NORTH CAROLINA
DEPARTMENT OF CONSERVATION AND DEVELOPMENT
HARGROVE BOWLES, JR., *Director*

Division of Mineral Resources
JASPER L. STUCKEY, *State Geologist*

Bulletin 76

# Geology and Mineral Resources of Moore County, North Carolina

By
JAMES F. CONLEY

RALEIGH
1962

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## Letter of Transmittal

Raleigh, North Carolina
May 2, 1962

*To His Excellency,* HONORABLE TERRY SANFORD
*Governor of North Carolina*

SIR:

I have the honor to submit herewith manuscript for publication as Bulletin 76, "Geology and Mineral Resources of Moore County, North Carolina", by James F. Conley.

This report contains the results of detailed investigations of the geology and mineral resources of Moore County and should be of value to those interested in the geology and mineral resources of Moore County and adjacent areas.

Respectfully submitted,

HARGROVE BOWLES, JR.
*Director*

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# GEOLOGY AND MINERAL RESOURCES OF MOORE COUNTY, NORTH CAROLINA

By

JAMES F. CONLEY

## INTRODUCTION

### Location and Area

Moore County is located in the south central part of North Carolina, between 35 degrees 04 minutes and 35 degrees 31 minutes north latitude and 79 degrees 12 minutes and 79 degrees 46 minutes west longitude. The county is irregular in outline with much of its boundary following streams and other natural features. It is bounded on the north by Randolph and Chatham counties; on the east by Lee, Harnett, and Cumberland counties; and on the west by Richmond and Montgomery counties. Scotland County lies immediately to the south, but has a common boundary at only one point. Moore County contains about 862 square miles and ranks 18th in size among the 100 counties of the State.

### Purpose and Scope

A geologic mapping program was initiated in Moore County, North Carolina in the fall of 1959 by the North Carolina Division of Mineral Resources. The purpose of this research program was: (1) map the geology in as much detail as time permitted; (2) locate both the active and abandoned mines, study their economic possibilities, mode of origin and relationship to the regional structure; and (3) attempt to locate new mineral deposits which might be of economic value.

Only the southern half of the county is covered by topographic maps. Therefore, a base map for the northern half was prepared from aerial photographs at a scale of one inch equals one mile. The geology was plotted directly on contact prints and transferred to the base map.

In the area underlain by rocks of the Carolina Slate Belt, outcrops vary from poor to non-existant and in several instances saprolite and soils had to be relied on to deduce the underlying rock type.

Outcrops in the Coastal Plain are better exposed, except in a few instances where drainage is poorly developed. The northern part of the Triassic Deep River basin was mapped by John A. Rinemund (1955) during the period 1946-1949. Portions of his map are reproduced as part of the geologic map accompanying this report, with only minor changes.

## GEOGRAPHY

### Culture

Moore County was established on July 4, 1784, from land which originally comprised part of western Cumberland County. An additional tract bounded by James Creek, Little River, Hector Creek, and the Harnett County line was transferred from Hoke County in 1959. The county was named in honor of Alfred Moore, a military colonel in the American Revolution. Carthage, located near the center of the county, was established as county seat in 1803 and has served in that capacity since. Other principal towns include Aberdeen, Pinehurst, Robbins and Southern Pines.

The county is served by three railroads. The Seaboard Air Line Railroad passes through the towns of Cameron, Vass, Southern Pines, Aberdeen and Pinebluff and is the main north-south route. The Norfolk Southern Railway has two east-west lines which serve the area. One crosses the northern part of the county passing through Glendon and Robbins, and the other, located in the southern part, passes through Aberdeen, Pinehurst and West End. From Aberdeen, southward, the area is served by the Rockfish and Aberdeen Railroad. A network of federal, state and county roads provide easy access to all parts of the county. In addition, regularly scheduled airlines operate out of Knollwood Airport, located a few miles north of Southern Pines.

Moore County has a well balanced economy and a great variety of income-producing resources. Among the major of these are agriculture, mining, recreation, and retail and wholesale trades.

### Climate

Moore County is noted for its hot summers and mild winters, which make it a "mecca" for winter golfing and equestrian sports. The mean annual temperature is 61.1° F. The summer temperature averages 73.2° F; the winter temperature raverages

50.2° F. The average precipitation is 44.61 inches, most of which occurs in the spring and early summer (U. S. Weather Bureau, 1961).

### Physiography

Moore County contains parts of two of the major physiographic provinces of the United States. The northern two-fifths of the county lies within the Piedmont Plateau province, locally referred to as the "clay country", whereas the southern three-fifths of the area is in the Sandhills subdivision of the Atlantic Coastal Plain province.

In the area where the softer unconsolidated materials of the Coastal Plain come in contact with the more resistant rocks of the Piedmont, there is a relatively narrow transition zone which in other places is marked by an abrupt change in relief. This contact is referred to as the Fall Line or Fall Zone. The Fall Zone occurs in Moore County as an uneven contact from near White Hill at the northeastern boundary westward through Carthage to a point on the western boundary about two miles north of Highway N. C. 211. In contrast to other areas, the Fall Zone in Moore County is a conspicuous topographic ridge which forms a drainage divide between northeast and southeast flowing streams.

A third physiographic subdivision is the Triassic basin which lies in a northeast-southwest direction across the county. This depression or trough is about 10 miles wide and is tarecable from the northeast corner of the county southeastward to Harris, where it is covered by the sediments of the Coastal Plain. Even where covered by the Coastal Plain, the area underlain by Triassic sediments is lower than the surrounding countryside. The Triassic basin contains relatively soft sedimentary rocks which are much less resistant to erosion and have been removed at a more rapid rate than the crystalline rocks of the uplands to the west.

### Topography

Moore County is an area of contrasting topography. The uplands, underlain by crystalline rocks range in elevation from 600 feet above sea level in the northwestern part of the county to only 300 feet in the northeastern part. Topography is typical of the Piedmont with rounded hills and V-shaped valleys. The hilltops rise from 75 to 100 feet above the valley floors, with a few rising as high as 150 feet.

The Triassic basin ranges in elevation from 250 to 500 feet. The eastern and western rims of the Triassic basin lie as much as 250 feet above its floor and form prominent escarpments. From the escarpments the land slopes rapidly to the basin floor. Northeast trending ridges of low relief occur in the basin. These usually do not rise more than 75 feet above the valleys. Valleys in the Triassic basin are wider than in the uplands and some contain floodplain deposits.

The average elevation of the Coastal Plain is about 400 feet; however, it ranges from 500 feet along its northern limits to less than 190 feet in river valleys at the extreme eastern tip of the county. The Coastal Plain is sculptured into alternating flat-topped ridges with convex sides that rise as much as 150 feet above broad, flat valleys filled with floodplain deposits. This topography is typical of the Sandhills region. Relief is considerably greater than found in the Coastal Plain outside of the Sandhills.

### Drainage

Moore County is drained by three major streams; Deep River, Little River, and Drowning Creek. Deep River enters the county along its north-central border and flows in a semicircle leaving the county at its northeastern corner. It drains almost all of the northern half of the area and has several major tributaries, including Bear Creek, Buffalo Creek, Falls Creek, McLendons Creek and Governors Creek.

Little River heads up in central Moore County and flows eastward draining the central and east-central part of the area. Its main tributaries are Crane Creek, James Creek and Nicks Creek.

The southwestern and southern boundary of the county is formed by Drowning Creek, which also drains this area. Its major tributaries are Jackson Creek, Horse Creek, and Aberdeen Creek.

## GEOLOGY

### The Carolina Slate Belt

The northwestern part of Moore County is underlain by low-grade metamorphic rocks of volcanic and sedimentary origin. The area in which these rocks crop out is known as the Carolina Slate Belt. The name Carolina Slate Belt was first applied by Nitze and Hanna in 1896. This name is a misnomer and should be replaced because the predominant rocks are not slates, and they do not form a belt. West of Moore County they are dominantly argillites, but in the county they are mostly phyllites with some slates. Although the outcrop area appears as a belt, it is now known that these rocks extend under the Coastal Plain for a considerable distance. This is indicated by oil-test wells drilled in Bladen and Pender Counties, which bottomed in these rocks.

In 1822 Olmstead described novaculite, slate, hornstone, and talc from areas now known to be underlain by the Carolina Slate Belt. In 1825 he referred to the "Great Slate Formation", which "passes quite across the state from northeast to southwest, covering more or less the counties of Person, Orange, Chatham, Randolph, Montgomery, Cabarrus, Anson and Mecklenburg". He described the rocks of this "formation" as consisting of clay slate or argillite porphyry, soapstone, serpentine, greenstone and whetstone. Eaton (1820) in a report on gold in North Carolina, added "talcose slates" to the list of rocks occurring in the belt. He stated that they occur in association with novaculite.

Ebenezer Emmons (1856) probably one of the most competent geologists of his time, placed these rocks in his Taconic system which he divided into an upper and a lower member. He considered these rocks amongst the oldest in this county. The upper member consisted of clay slates, chloritic sandstones, cherty beds, flagstones, and brecciated conglomerates. The lower member consisted of talcose slates, white and brown quartzites and (on his cross section, Plate 14, he added) conglomerate.

Emmons, not recognizing volcanic rocks in his series, considered them water-laid sediments. The divisions of his system into an upper and a lower member is used, with modifications, in this report.

Kerr (1875) described the rocks of the Carolina Slate Belt and proposed that they were of Huronian age. Williams (1894) first recognized volcanic rocks in the Carolina Slate Belt. Becker (1895) published a paper recognizing the presence of volcanic rocks in the sequence and proposed that they were Algoncian age.

Nitze and Hanna (1896) recognized volcanic rocks interbedded with the slates that they proposed were laid down during times of volcanic outbursts, followed by inactivity during which time slates were deposited. They noted that some of the rocks had true slaty cleavage, whereas others were truly schistose. They believed these rocks were altered by dynamo-and-hydro-metamorphism.

Weed and Watson (1906) studied the Virgilina copper deposits and proposed that the country rocks were metamorphosed andesites. The age was thought to be Precambrian.

Laney (1910) described the Gold Hill Mining District of North Carolina. In this report he divided the rocks into slates with interbedded felsic and mafic flows and tuffs. He stated that the slates differ from the fine, dense tuffs only in the amount of land waste they contain, indicating that the slates, in part, were derived from volcanic material. He did not define "land waste", nor did he explain how it might be recognized. He stated that the rocks all show much silicification and are only locally sheared. He proposed that a major fault, the Gold Hill fault, separated the igneous rocks to the west from the slates. Pogue (1910) described the Cid Mining District, and Laney (1917) described the Virgilina Mining District. Interpretations in these reports are, in general, repetitions of ideas as expressed in Laney's report of 1910.

Stuckey (1928) presented a report which included a geologic map of the Deep River Region of Moore County. He divided these rocks into slates, acid tuffs, rhyolites, volcanic breccias, and andesite flows and tuffs. He noted that the schistosity dipped to the northwest and interpreted the structure as closely compressed synclinorium with the axes of the folds parallel to the strike of the formations. He stated (p. 23) "The minor folds dip steeply to the northwest side of the troughs and flatten out to the east. The synclinal troughs pitch and flatten out in places as is indicated by the way the slate bands, which are all synclinal in structure, occur in long narrow lenses often pinching out. This pinching and flattening indicates some cross folding". He noted the slates seem to have consolidated readily and to have folded as normal sediments; whereas, the tuffs and breccias remained in a state of open texture and tended to mash and shear instead of folding. He stated that there is little evidence for faulting, although minor displacements amounting to a few inches were noted. Stuckey, from a comparison of his investigation with work by Laney and Pogue, concluded that the rocks of the whole slate belt are of the same general types. He noted that metamorphism is not uniform throughout the area.

Theismeyer and Storm (1938) studied slates near Chapel Hill that showed fine-graded bedding, and proposed that they represented seasonal banding. Theismeyer (1939) proposed that similar sediments found in Faquier County, Virginia, were deposited in pro-glacial lakes during late Precambrian and early Cambrian times. The bedding is thought to be seasonal "varves". In addition he proposed that "the Hiwassee slates of Tennessee and the slates in North Carolina, near Chapel Hill, belong to the same category; even may have been deposited more or less contemporaneously".

## Stratigraphy

The rocks of the Carolina Slate Belt have been divided, by Conley (1959) and Stromquist and Conley (1959) in the areas covered by the Albemarle and Denton 15-minute quadrangles, into a lower unit composed of volcanic rocks, a middle unit composed of volcanic and sedimentary rocks, and an upper unit of volcanic rocks which unconformably overlies the two lower units. In Moore County only the lower and middle units appear to be present; however, some rhyolites in the area might belong to the upper unit. The exact stratigraphic relationships of some of the rocks in the county are in doubt because of the gradational nature of the contacts, a condition further complicated by intense folding and faulting and lack of outcrops.

### Lower Volcanic Sequence

*Felsic Tuffs and Flows*: Rocks of the Lower Volcanic sequence are the oldest rocks exposed in the county. This unit on the order of 3500 feet thick, is composed predominately of fine, usually sheared, felsic crystal tuffs. The tuffs vary in color from white or light cream to light grey. They weather white and sometimes white weathering rinds are observed on fresh rock. Topsoil developed on these rocks is a cream-colored silty loam; the subsoil is a white clay loam. The rocks are usually massive. However, in a small area on Mill Creek west of West Philadelphia, they contain obscure bedding planes.

In thin section the tuffs are composed of quartz, orthoclase, and plagioclase, probably albite in composition, in a fine groundmass of what appears to be cryptocrystalline quartz accompanied by sericite and kaolinite. Feldspars appear as clouded, angular lath-shaped fragments partly replaced by sericite. The sheared appearance is much more apparent in thin section than in hand specimen. The quartz grains are crushed and drawn out in the direction of shearing. The groundmass has a banded appearance resulting from segregation of kaolinite and sericite along planes of shear.

Interbedded with the felsic crystal tuffs are felsic lithic-crystal tuffs, rhyolites, and mafic crystal tuffs. The contact between the felsic crystal tuffs and the felsic lithic-crystal tuffs usually is gradational with well defined contacts being the exception. The lithic-crystal tuffs have the same matrix composition as the crystal tuffs, but in addition contain grey porphyritic, rhyolite fragments which range from one eighth of an inch to more than six inches in diameter. These fragments range from well rounded to highly angular masses; others appear to be flattened. The groundmass is now composed of cryptocrystalline quartz, sericite and kaolinite. The phenocrysts consist of quartz and lath-shaped orthoclase and plagioclase feldspars, the latter varying in composition from albite to oligoclase. Some of the tuffs are welded and exhibit flow lines. They could easily be mistaken for rhyolites if it were not for the presence of lithic fragments. The flow lines usually are well defined in thin section due to the development of sericite along the flow structures.

The rhyolites occur in small outcrops in the extreme northwestern corner of the county near West Philadelphia and on the hill above the Dry Creek pyrophyllite mine. Rhyolites are difficuilt to differentiate from flow tuffs, even in unmetamorphosed rocks, and these may be flow tuffs. They are classified as rhyolites on the basis of swirl flow banding, euhedral feldspar phenocrysts, and the absence of either broken crystal of lithic fragments.

The rhyolites are porphyritic, containing visible feldspars up to one-sixteenth of an inch in length. They are light grey in color, weathering to chalky white on the surface. They are exceedingly dense, emitting a metallic ring when struck with a hammer. This rock usually is not sheared even when tuffs on either side of some outcrops have suffered considerable shearing. They contain prominent swirl-banded flow lines which are accentuated by weathering. Because of their resistance to weathering the rhyolites form elongate hills. Soils developed on the rhyolite are extremely shallow, ranging from 12 to 15 inches in thickness.

In thin section, the rhyolites are composed of aggregates of unoriented, interlocking, angular, quartz grains; untwinned orthoclase; and albite and carlsbad twinned oligoclase. The groundmass is exceedingly fine and can not be resolved to individual crystals, but appears to be an interlocking network of cryptocrystalline quartz, sericite and kaolinite.

*Mafic Tuffs*: The mafic tuffs shown on the geologic map (Plate 1) are not limited to any one rock sequence, but are found interbedded with the felsic tuffs, and andesitic tuffs of the Lower Volcanic sequence as well as slates of the overlying Volcanic-Sedimentary sequence. However, mafic tuffs are more frequently associated with the andesitic tuffs. Evidently, outburst of mafic ejecta occurred over a considerable span of geologic time. Because of the lithologic similarity of the mafic tuffs they are all shown, for convenience, as the same color on the map.

These rocks in general are andesitic in composition, but contain some material that might be classified as basalt. They are composed of lithic fragments ranging from one-sixteenth of an inch up to eighteen inches in diameter, and crystal fragments, ranging from microscopic up to one fourth of an inch in diameter. From place to place, the ratio of crystals to lithic fragments is exceedingly variable, as is the size of the clastics making up the rock.

The tuffs usually are sheared. They have a greyish-green or olive-green color when fresh, becoming dun-brown on weathering from the oxidation of their iron. Topsoils developed on these rocks are tan-colored silty loams; the subsoils are usually dark-brown to chocolate-brown colored heavy clay loams.

In thin section the matrix of the rock appears to be made up almost entirely of chlorite bands strung out parallel to shearing. Feldspars have been altered to sericite and kaolinite. In highly sheared rocks, phenocrysts have been rolled parallel to schistosity and have an augen-like appearance. One thin section contained quartz masses that appear to be crushed, unoriented, and strung out parallel to schistosity. These quartz masses might be secondary fillings of vessicles.

The lithic fragments appear to be of different composition than the matrix of the rock. Some specimens are composed of a mesh of lath-shaped feldspar crystals about 0.02 of a millimeter in length with chlorite filling the interstices. Augite, not altered to chlorite, is present in rare isolated fragments. The groundmass of some of the fragments is composed of sericite and kaolinite rather than chlorite.

In general, the rock is not bedded. However, in the area north of High Falls the mafic tuffs contain numerous interbeds of graywacke. These interbeds range from a few tens of feet to more than over a hundred feet in thickness. The graywacke is greenish-grey when fresh, becoming light-brown on weathering. It is composed of quartz, feldspar, rock fragments, and a small quantity of argillaceous material. The rock exhibits graded bedding consisting of coarse sand, rock fragments up to two centimeters across, and intermixed fine sand at the base, which grades upward into fine sand at the top of the bed. The rock fragments, so prominent in hand specimen, are reduced in thin section to aggregate of kaolinite, chlorite and sericite. This suggests that the fragments are completely altered and are only recognizable in hand specimen by the preservation of relic structures.

*Andesite Tuffs*: The andesite tuffs are about 2500 feet thick and are composed of interbedded crystal tuffs, lithic-crystal tuffs, argillaceous lithic conglomerates, argillaceous beds and questionable flows. These tuffs are highly susceptible to shearing and usually exhibit axial plane cleavage. Many of them are sheared and pass into phyllites in which primary fragments are flattened and elongated in the direction of movement. The andesite tuffs have a distinctive greyish-purple color when fresh, and on weathering become a lighter purple. This coloring is due to primary hematite in the rock. Topsoil developed on the andesite tuffs is a dark, red-clay loam and the subsoil is a dark-maroon to maroonish-purple colored heavy plastic clay.

Crystal fragments in the more tuffaceous phases rarely exceed 40 percent of the composition of the rock. They consist almost entirely of lath-shaped feldspar fragments and rare euhedral crystals, ranging in length from microscopic to three millimeters. The feldspars are highly sericitized and are both carlsbad and albite twinned. Gross composition is approximately that of andesine. In addition to feldspar, lath-shaped masses of chlorite are also present. This chlorite probably represents altered amphibole and pyroxene. Quartz is rare in the crystal tuffs; however, one questionable flow tuff consisted of 30 percent of almost spherical quartz grains ranging up to two millimeters across. This is probably secondary quartz filling vessicles. The interstices are filled with hematite which obliterates the groundmass.

Lithic-crystal tuffs are readily differentiated from argillaceous lithic conglomerate. The fragments are angular and the matrix contains crystal fragments in the lithic tuffs; whereas, the fragments are rounded and the matrix is argillaceous in the lithic conglomerates. The rock fragments in both the tuffs and conglomerates are similar in composition. They rarely exceed two inches in diameter in the conglomerates, but range up to ten inches across in the tuffs. Megoscopically these fragments are of two types. One is a massive aphanite, and the other is a crystal flow rock. Microscopically the aphanite fragments consist almost entirely of sericite and hematite; the flow-rock fragments appear as an aggregate of unoriented feldspar laths averaging about 0.02 of a millimeter in length in a matrix of hematite. Aside from flow lines and crystals, the original composition and texture of the flow rock fragments are masked by hematite.

The groundmass of the tuffs is so fine grained that it can not be resolved under the microscope. It appears to be composed predominately of elongate masses of opaque hematite, sericite, chlorite, and kaolinite. Epidote occurs sparingly in some thin sections. The matrix of the argillaceous rocks is even finer grained and also is obscured by hematite.

Near the top of the stratigraphic section the andesite tuffs become more argillaceous and bedding is observed more frequently. As the contact with the overlying slates is approached, graded bedding, so common in the slates, begins to predominate.

### Volcanic-Sedimentary Sequence

*Slates*: The slates are about 6,000 feet thick and form the basal unit of the Volcanic-Sedimentary sequence? They attain the greatest elevation of any stratigraphic unit found in Moore County? There is no sharp contact between this rock and the underlying andesitic tuffs, but there is a gradational stratigraphic change from tuff to slate. Fine graded bedding, resembling varved bedding, is a characteristic of the slates. The bedding planes vary from one-sixteenth to one-fourth of an inch in thickness. Axial plane cleavage usually is more pronounced than bedding. The fresh slate is dark grey in color and weathers to ocherous reds and yellows. Topsoils are usually light brown-colored silts; whereas, subsoils are light red silty loams.

In thin section graded bedding is easily observed. It consists of a silt layer at the bottom which grades upward into clay layer. The silt sized particles predominately consist of quartz grains as well as some feldspar and what were probably ferromagnesian minerals, now chloritized. The clay layers are now predominately sericite. The slates outcropping in the eastern part of the county, along the western contact with the Triassic basin, contain interbeds of graywacke sandstone, which in places make up as much as fifty percent of the rock. These graywackes have a different composition and texture than those interbedded with the mafic tuffs. They are greyish-green when fresh and weather light maroon. They usually appear to be massively bedded; however, closer inspection reveals thin bedding planes and graded bedding ranging in size from sand at the bottom to silt at the top. The rock is composed of equal parts of chloritized rock fragments and quartz with occasional grains of albite-twinned sericitized feldspar which ranges in composition from oligoclase to andesine. The rock varies in composition from the base to the top of the graded beds. The matrix filling the interstices between the sandgrains in the lower parts of the beds consist of about equal parts sericite and kaolinite with a trace of chlorite. As the beds become finer grained toward the top, chlorite increases until the upper silt fraction of the bedding is composed of approximately sixty percent chlorite, fifteen percent sericite, fifteen percent kaolinite and ten percent quartz.

### Environment of Deposition

The Lower Volcanic sequence is thought to be volcanic ejecta deposited on land. This is indicated by the general angularity of lithic and crystal fragments and the general lack of sorting in the sediments.

Pillow structures, which only form in subaqueous flows, are not present in the interbedded rhyolites, even though flow lines are well preserved. If pillow structures had developed, they should be as well preserved as the flow lines.

The presence of welded flow tuffs also suggest subaerial deposition because it is unlikely these rocks could have retained enough heat to flow and weld if they were deposited in water. The tuffs on Mill Creek contain bedding and might be water laid. However, air laid tuffs often contain bedding and are deposited in water. The presence of graywacke interbeds in the mafic tuffs suggest an aqueous environment and turbidity currents. These graywackes were probably, for the most part, derived from reworking of the mafic tuffs. The coarse mafic-lithic breccias and mafic crystal tuffs, so commonly interbedded with the andesitic tuffs, were evidently blown out of volcanoes and deposited directly in water without reworking.

The numerous rounded lithic fragments, bedding planes, and fissle graded bedding suggest that the andesite tuffs were water laid. The presence of inter-bedded lithic-crystal tuffs and argillaceous lithic conglomerates of essentially the same chemical composition suggests that these rocks were derived from the same source. One probably represents volcanic ejecta deposited directly in water without reworking, and the other a reworked sediment.

The gradual increase in graded bedding toward the contact with the overlying slates suggest a change in environment from shallow to deep water. The andesite tuffs are thought to represent a transition unit and a transition environment between the terrestial tuffs and flows of the Lower Volcanic sequence and the deep-water sediments of the overlying Volcanic-Sedimentary sequence.

The slates were deposited in quiet water, below wave base. This is indicated by the fine graded bedding which could only develop in quiet waters.

The mechanism which produces fine graded bedding is not thoroughly understood. Theismeyer (1939) proposed that the slates were varved sediments deposited in pro-glacial lakes during late Precambrian or early Cambrian times. No glacial deposits have been identified in the rocks of the Carolina Slate Belt and this theory is not acceptable.

It has been suggested that varve-like graded bedding can only occur in water of low salinity because of flocculation. This is indicated by Fraser's (1929) experimental studies which showed the maximum salinity permitting the formation of varves of coarse clay to be about one fiftieth that of sea water. Pettijohn (1949) stated that graded bedding occurs in sediments from Precambrian to the present and suggested that flocculation by sea water is a doubtful concept. Kuenen and Menard (1952) believed that graded bedding in graywackes is caused by turbidity currents and can occur in normal sea water.

Two methods are proposed which might produce graded bedding in the slates. One postulates that the sediments were derived from silt and clay sized ash blown out of volcanoes. The larger sized particles would immediately settle out of the air allowing them to be deposited in the water first. The smaller sized particles would be thrown higher in the air and, buffeted by air current and take longer to settle out. This would produce a graded sediment due to air sorting before the material reached the water. The second method postulates that the graded bedding was produced by turbidity currents. During rainstorms, streams would become charged with sediments. Upon reaching the basin of deposition, the water charged with sediments would be more dense than water in the basin; and would move slowly down the sub-aqueous slope as a weak turbidity current. As this current moved outward it would deposit a silt layer. As it lost its turbidity and velocity, the clay sized particles would gradually settle out on top of the silt layer. The presence of graywacke sandstones containing graded bedding adds strength to the turbidity current theory, because graywackes are now usually regarded as turbidity current deposits (Pettijohn 1957).

## Structure

### Folds

*Troy Anticlinorium*: The major structure in Moore County is the Troy Anticlinorium, which trends in a northeast-southwest direction and plunges toward the southwest. This structure has been traced from southern Montgomery County to northern Randolph County. The anticlinorium is over 30 miles wide, lying between the Pee Dee River on the west and western Moore County in the east. The axis of the fold is located near Troy, Montgomery County, and the southeastern limb occupies northwestern Moore County. The felsic tuffs of the Lower Volcanic sequence crop out in the center of the structure, whereas the overlying andesite tuffs and slates dip off its southeastern flank.

*Minor Folds*: A series of usually double-plunging anticlines and synclines, varying in wavelengths from one to three miles are developed on the southeast flank of the Troy anticlinorium. These folds are overturned to the southeast and cleavage developed parellel to the axes of the folds dips monotonously to the northwest at angles varying from fifty-five to seventy degrees. Schistosity and shearing increased from northwest to southeast across the county. In the northwestern part of the county the Lower Volcanic sequence dips under the overlying rocks but reappears in the center of anticlinal folds across the central and southwestern part of the county. The slates, the youngest Carolina Slate Belt stratigraphic unit found in Moore County, occupy the center of a number of overturned synclines in the central and eastern part of the area. The slates are contorted into a series of undulating open folds varying in wavelength from ten to thirty feet across. These folds probably developed due to plastic flowage within the slates during regional folding.

### Faults

Faults can be divided into two groups; namely, northeast trending longitudinal faults developed parallel to the axes of folds, and northwest trending cross faults. Because of slippage parallel to the axes of overturned folds, many of the longitudinal faults are reverse in nature. The zones of displacement along the major northeast trending faults usually have been intruded by quartz veins and are occasionally silicified and mineralized. The quartz veins and silicified zones are invariably sheared, indicating movement occurred along these faults after intrusion of the quartz veins and silicification.

The cross faults have displaced the longitudinal faults in a number of places, clearly indicating that they developed after the longitudinal faults. Major movement along the cross faults was strike slippage. Along the Deep River in the northern part of the county these cross faults can be traced into the Triassic basin. The cross faults have displaced the Carolina Slate Belt units as much as a mile along the strike, but have displaced Triassic rocks only a few hundred feet. This indicates the major movement took place in pre-Triassic time with a later movement of much smaller scale taking place after deposition of the Triassic sediments.

### Longitudinal Faults

*Glendon Fault*: One of the major longitudinal faults in the area is the Glendon fault. It lies approximately three miles northwest of Glendon and can be traced from the northern county line southeastward to just north of Robbins. It strikes north 60 degrees and dips 60 to 70 degrees northwest.

Drag folds indicate that it is a reverse fault, with movement from northwest to southeast. It is offset by several cross faults along its length. A wide mineralized shear zone containing workable pyrophyllite deposits accompanies the fault. Movement along the fault has placed the andesite tuffs in contact with the slates, except north of McConnell, where it has placed felsic tuffs underlying the andesite tuffs in contact with the slates. This suggests that the throw in this area must be in the order of several thousand feet.

*Robbins fault*: The Robbins fault passes through the western city limits of Robbins and is traceable from approximately one mile north of Robbins, southeastward to approximately one mile northeast of West Philadelphia. It trends north 60 degrees east and dips northwest at approximately fifty degrees. Drag folds indicate that it too is reverse in nature and the hanging wall to the northwest moved upward over the footwall to the southeast. The shear zone accompanying this fault is as much as a mile wide and contains pyrophyllite and gold deposits. The reverse nature of this fault and presence of pyrophyllite deposits along its trace suggests that it is the same type as the Glendon fault. In fact, if the strike of the Glendon fault were extended to the southwest (see Plate 1), it would intersect the Robbins fault south of Robbins.

*Other Longitudinal faults*: A horst structure, lying between two north sixty-five degrees east trending vertical faults, occurs in the area between Putnam and Hallison. This structure places felsic tuffs of the Lower Volcanic sequence in contact with slates of the Volcanic-Sedimentary sequence. The andesite tuffs lying stratigraphically between the felsic tuffs and the slates are omitted, indicating a throw in the order of several thousand feet. This horst is adjoined on the northwest by a graben which lies between the fault north of Putnam and the Glendon fault.

*Cross faults*: Vertically dipping northwest trending normal cross faults, which strike from thirty to seventy degrees northwest, occur throughout the central and eastern part of the county. Some of these appear to be hinge faults; whereas others show strike slippage. A number of strike-slip faults along Deep River have a horizontal displacement varying from half a mile to over a mile. The Deep River has entrenched along these faults producing a series of parallel meanders.

Southeast of Spies a pair of northwest-trending faults have produced a graben structure, downfaulting andesite tuffs against felsic tuffs.

A number of transverse faults have been intruded by diabase dikes. The dikes evidently were emplaced along zones of weakness; however, it is not understood why they preferred northwest trending faults and generally ignored those trending northeast.

## DEEP RIVER TRIASSIC BASIN

The Deep River Triassic basin lies in a northeast-southwest direction across Moore County. In the northern part of the county it is bounded on either side by the Carolina Slate Belt. In the southern part of the county it is overlapped by Coastal Plain sediments.

Emmons (1852) on the basis of fossil and lithologic evidence, concluded that the sediments of the Deep River basin were Triassic age. However, in 1856 he proposed that the lower sandstones and coal beds were of Permian age, because of the presence of Thecodant saurian teeth in some of the shales associated with the coal beds. Overlying sandstones were still considered Triassic age.

Redfield (1856) found that the rocks in New Jersey, Eastern Pennsylvania and in the Connecticut Valley were Upper Triassic age and proposed that they be named the Newark group. He found that fossil vertebrates in Emmons collection were identical to those occurring in the northern basins and correlated sediments in the Deep River basin with the Newark group.

Rocks of the Deep River basin consist of red, maroon, reddish-grey fanglomerates, conglomerates, sandstones and siltstones. In addition the basin contains coal beds and associated grey and black shales, mudstones, siltstones and sandstones.

Emmons (1852) subdivided the stratigraphy of the Deep River Basin into three units. These are:

3. Sandstones, soft and hard with freestones, grindstone grits, and superior conglomerates; cropping out along the eastern edge of the basin.

2. Coal beds and black slates with their subordinate beds and seams; cropping out in the center of the basin.

1. Inferior conglomerates and sandstones below the coal beds and black slates; cropping out along the western edge of the basin.

This was a logical conclusion because the strata dip toward the eastern edge of the basin. Although he devised this classification, Emmons (1856) recognized marked resemblance between certain strata on the eastern and western part of the basin and suggested that they might be the same unit.

In 1856 he repeated this classification in his text;

however, on the map accompanying the report, inserted an additional unit which he called "Salines" between the middle and upper units. Campbell and Kimball (1923) stated that the "Salines" are nothing more than drab shales, containing salt, above the coal beds, and belong with the middle division.

Campbell and Kimball (1923) mapped and named Emmons' three units calling the lowest the Pekin formation, the middle the Cumnock formation and the upper the Sanford formation.

Prouty (1931) discussed the formation of the Deep River basin. He proposed that it was caused by downwarping aided by development of an eastern border fault.

Reinemund (1955) published a detailed study of the structure and stratigraphy of the Deep River basin with special emphasis on the economic geology.

### Stratigraphy

*Pekin Formation*: Campbell and Kimball (1923) named the basal Triassic unit, the Pekin formation after a small town in southern Montgomery County. No type section or type locality was established, but they stated that it is best exposed on the road trending due east from Mt. Gilead. The formation underlies the western third of the Deep River basin in Moore County and is exposed along the western border of the basin from Deep River southward to the Coastal Plain overlap. The formation is estimated to be from 1750 to 1800 feet thick. Its basal part is supposed to rest on the eroded surface of the Carolina Slate Belt, (Reinemund 1955). To the south, along Drowning Creek, the western border of the basin is flanked by a lithic fanglomerate composed of angular to subrounded rock fragments, derived from the Carolina Slate Belt, ranging from one inch to over a foot in diameter.

An elongate conglomerate bed, lenticular in outline, resembling a shoestring sand lies along the western border of the northern part of the basin. This bed was extensively quarried before 1900 to make millstones, and is known locally as the Millstone Grit.

The bed varies in thickness from 2 to 30 feet, and is composed of quartz pebbles, varying from one to three inches in diameter, in a matrix of coarse sand. The conglomerate is well cemented and the pebbles can be broken without being dislodged from the matrix.

A paleosoil underlies the Millstone Grit in an outcrop on Highway N. C. 22 at the old Parkwood quarry. It is a grey, carbonaceous, partly-kaolinized clay containing numerous root impressions.

East of the western border, the Pekin formation is composed of lenticular beds of red, brownish-red, and maroonish-purple clayey siltstones, sandstones and occasional beds of brown or grey, medium to coarse grained, cross bedded, arkosic sandstones and conglomerates. Rare thin beds of claystone are also present. Many of the sandstones contain root impressions on weathered surfaces.

Toward the center of the basin the sediments become finer grained, with siltstones predominating. To the southeast the sediments become progressively coarser, and frequently contain more arkosic beds as well as coarse-grained, grey-colored, cross-bedded sandstones.

*Cumnock Formation*: Campbell and Kimball (1923) named the middle coal-bearing Triassic beds the Cumnock formation after the Cumnock mine. The type section was located in the main shaft of the mine. The Cumnock formation is exposed in northern Moore County from Deep River southward to the Coastal Plain overlap. On the road between Glendon and Carthage it is repeated four times by faulting.

In the north-central part of the basin the Cumnock formation is 750 to 800 feet thick and consists of coal, black and grey shales, with thin sandstone beds in the middle and upper part (Reinemund 1955). The Pekin-Cumnock contact was placed by Emmons at the top of the last redbed below the coal beds, and the Cumnock-Sanford contact at the first redbed above the coal. The two workable coal beds occur about 200 feet above the base of the Cumnock formation. The lower coal bed, called the Gulf seam, has been found only at the Carolina and Black Diamond mines and lies from 25 to 45 feet below the second, or Cumnock bed (Reinemund 1955).

The Cumnock formation and associated coal beds is the thickest near the center of the basin, thinning rapidly toward the edges. The formation is best developed at Carbonton and Gulf and apparently thins rapidly to the southwest. This is indicated by the Cumnock coal bed which is reported to be 42 inches thick at Cumnock, but only 14 inches thick at an exposure at the Gardner mine. Campbell and Kimball (1923) noted the area, two miles wide, northwest of Carthage in which the Cumnock formation does not crop out. They postulated that this might be caused by either lateral gradation of the grey Cumnock strata into the red beds of the Pekin and Sanford formations, or down faulting, but seemed to favor faulting as the explanation.

The Cumnock formation dips under the Coastal Plain sediments four miles southwest of Carthage, and has not been observed in outcrop south of the point. An exception to this might be the grey siltstone and mudstone exposed in a stream valley one and one-half miles southwest of Eagle Springs, on the road to Samarcand Manor. Whether or not this is actually the Cumnock formation or a variation of the Pekin formation is open to question, because this exposure lies considerably north of a projection of the last Cumnock outcrop. It is thought that the reason the Cumnock formation does not crop out south of Carthage is because it is downfaulted along the continuation of the Governors Creek fault. The Cumnock formation reappears further to the southwest as indicated by a coal prospect located in Montgomery County near the Moore County line.

*Sanford Formation*: The Sanford formation was named by Campbell and Kimbell (1923) after the town of Sanford and included all rocks above the Cumnock formation. The Sanford formation conformably overlies the Cumnock formation, and in Moore County this contact might best be described as gradational. The Sanford formation is estimated to be from 3500 to 4000 feet thick (Reinemund 1955) and covers the eastern half of the Deep River basin. Reinemund (1955) stated that the Sanford formation contained few distinctive beds which can be traced over any appreciable distance. The beds are lenticular and laterally gradational. Measured sections would only apply to rocks in the immediate vicinity and correlation is not feasible over wide areas.

The Sanford formation similar to the Pekin formation, is predominately a sequence of redbeds. It also is composed of sandstones, siltstones, conglomerate and fanglomerate. To the southwest, the formation becomes progressively coarser and contains more frequently occurring beds of coarse arkosic sandstone.

Fanglomerate crops out, in a belt varying in width from three-fourths to over a mile wide, along the southeastern edge of the basin. It is composed of unsorted rock fragments ranging from one-half an inch to more than a foot in diameter. These fragments were derived from rocks of the Carolina Slate Belt and usually are poorly indurated. Material filling the interstices between the fragments usually is composed of red and maroon sandstones and siltstones. The fanglomerate shows very poor bedding; however, the general dip of the rock can be ascertained by observing the orientation of tabular rock fragments. From the eastern border and toward the center of the basin, the fanglomerat grades laterally into conglomerate. In addition to the fanglomerate, the Sanford formation contains well-defined lenticular beds of quartz conglomerate which are sometimes cross-bedded. These lenses usually grade into sandstones.

Beyond the border of the basin the majority of the Sanford formation consists of interbedded red and maroon siltstones and sandstones. Claystones and shales are almost totally absent. The coarser sandstones are most prevalent along the eastern edge of the basin with siltstones becoming predominant toward the center of the basin. These sandstones are similar to the sandstones of the Pekin formation, along the northwestern edge of the basin and contain numerous root impressions.

*Unnamed Upper Conglomerate*: Northeast of Carthage a grey conglomerate lies on the eroded surface of the Sanford formation (see Plate 1). Probably the best exposure is in a new road cut on a hill rising above the east bank of the east fork of Big Governor's Creek. The conglomerate consists of well rounded quartz pebbles, ranging in size from one-half to two inches in diameter, intermixed with a minor amount of coarse angular sand. In addition it contains minor lenses of siltstone. The rock is poorly consolidated and usually is not stained with the red iron oxides as generally is the case with Triassic rocks. The Triassic age of the conglomerate is well established because it has been intruded by a diabase dike.

After observing this conglomerate, J. L. Stuckey informed the author that similar gravels occur near Apex, North Carolina. The Apex locality was visited by Reinemund and Stuckey in 1948, at which time they reached the conclusion that the gravels were of Triassic age and appeared to be younger than the Sanford formation.

It might be argued that these gravels are part of the Sanford formation because unconformable beds within the formation are relatively common. This possibility certainly cannot be ruled out. However, a better explanation is that these gravels probably are post Sanford floodplain deposits as indicated by the preservation of old stream channels.

*Triassic Diabase*: Diabase dikes generally regarded to have been emplaced in late Triassic time, have intruded both the Deep River Triassic basin and the Carolina Slate Belt. In the Deep River basin a number of dikes have intruded the Sanford formation northwest of White Hill. Dikes and large sills have intruded the Cumnock formation northeast and southeast of Glendon. Dikes occasionally occur in the Pekin formation west of Carthage. Diabase dikes have been mapped in the Carolina Slate Belt and are most numerous in the area between High Falls and Parkwood.

The diabase dikes in general trend northwest, with a few exceptions trending either north or northeast. These dikes dip either vertically or slightly to the northeast. They range in thickness from one to several tens of feet. Diabase dikes occurring in the Carolina Slate Belt are usually smaller than those in Triassic sediments. This leads to the conclusion that the magma could more easily intrude and incorporate the less resistant Triassic sediments. The existence of low refractory shales and coal in the Cumnock formation might explain why large sills occur in this unit. Even where they intrude Triassic sediments, the baked zones on either side of the diabases are rarely over twice the thickness of the dikes, and in the Carolina Slate Belt these zones do not exceed a few inches. The baked zones usually are dark grey at the contact with diabase, becoming reddish grey away from the contact.

The diabases are exceedingly susceptible to spheroidal weathering producing rusty boulders scattered through the surficial soil. Soil, developed on weathered diabase is a conspicuous dark-yellow brown, but occasionally is a dark-chocolate brown.

During the field investigation for this report little attention was given to the petrography of the diabase dikes. Reinemund (1955) studied the diabases in detail. He found that they contain the primary minerals olivine, plagioclase feldspars, varying from andesine to bytownite, augite, orthoclase and quartz; the accessory minerals magnetite, ilmenite, pyrite, chromite, titanite, apatite, and basaltic hornblend; and secondary minerals antigorite, limonite, hornblende, calcite, and magnetite. Olivine is usually present in varying amounts. The rock usually contains as much as two-thirds plagioclase and as much as one-third augite. In addition to normal diabase, gabbroic varieties composed of one-half olivine and one-third plagioclase and dioritic diabase composed of one-half plagioclase and one-third augite are present.

## Envioronment of Deposition

Kryniene (1950) expressed the opinion that red color of the Triassic sediments was due to erosion of red soils in the source area. Reinemund (1955) essentially agreed with this, and added that the dark brown and red colors of the Pekin and Sanford formations indicated that the sediments were deposited in a non-reducing environment.

During the time of deposition of both the Pekin and Sanford formations fluvial conditions existed in the Deep River basin. At this time both the border faults had well defined scraps. Talus material accumulated at the base of these scarps producing the fanglomerates found in the Pekin formation along the western edge of the basin and the Sanford formation along its eastern edge.

From the edges toward the center of the basin, sediments of both formations become progressively finer grained. Reinemund (1955) stated that sediments of the Pekin and Sanford formations were deposited by streams, as indicated by the cross bedding and the channel like form of some of the coarse grained sediments. Root impressions, commonly found in the sandstones of these formations, suggest that much of the area between the major stress channels was marshland. General coarsening of the grain size of the sediments to the southwest indicate that drainage within the basin was in that direction.

Gradual sinking of the basin probably occurred during sedimentation by slight movements along the border faults, causing rejuvination from time to time of streams flowing into the basin. During the latter part of Pekin sedimentation the scarp of the Western border fault in the northern part of the county did not stand at elevations great enough to produce talus deposits. At this time, a stream, incised along the fault scarp, deposited the Millstone Grit.

The occurrence of the Cumnock formation, with its black shale and coal beds in the center of the basin, represents a change from stream and shallow marshes, with rapid sedimentation along the margins of the basin; to a shallow lake, with slow sedimentation in the center of the basin. A shallow body of standing water could support a lush growth of vegetation. After death the organic remains would fall to the bottom of the lake and be protected from oxidization. Extremely slow sedimentation would allow accumulation of organic material of thickness and purity to form workable coal beds.

After the basin had filled with sediments, streams meandered over its surface depositing the unnamed, upper gravels which overly the Sanford formation.

It is suggested that deposition of parts of the Pekin, Cumnock and Sanford formations, as mapped, might have occurred simultaneously. Only in areas of outcropping Cumnock formation can the names Pekin and Sanford formations be used as time-stratigraphic units. In these areas redbeds underlying and in direct contact with the Cumnock formation can definitely be called the Pekin formation, and inversely, the redbeds overlying the Cumnock formation belong to the Sanford formation. Because grey shales and coal beds of the Cumnock formation are limited to the center of the basin, redbeds deposited along the eastern and western margins of the basin during Cumnock time are most likely mapped as Sanford and Pekin formations respectively. As no key horizons exist along the margins of the basin, it would be best to regard what has been mapped in these areas as Pekin and Sanford formations as sedimentary facies rather than time-stratigraphic units.

### Structure

*Folds*: The Deep River basin has been described by Campbell and Kimball (1923) and by Reinemund (1955) as a synclinal basin. In this paper the basin is considered a graben structure in which the beds dip monoclinally to the south-east. The syncline which Reinemund (1955) regarded as the axis of the basin occurs northeast of White Hill. Another small syncline lies along the west bank of McLendon's Creek, where Highway N. C. 27 crosses the creek. Approximately eight tenths of a mile north of this area is located the axis of a small anticline. Folds of large magnitude have not been observed within the Deep River basin in Moore County.

*Faults*: Reinemund (1955) found three ages of faults in the Deep River basin. The oldest is the Jonesboro fault or eastern border fault, which remained active during sedimentation; the cross faults are next in age, developing after sedimentation had ceased; and the longitudinal faults are the youngest. This is indicated by the fact that the cross faults have displaced the Jonesboro fault, but not the longitudinal faults. In turn, the longitudinal faults have offset the cross faults, but are not offset by the cross faults.

### Border Faults

*Jonesboro Fault*: The Jonesboro fault was named by Campbell and Kimball (1925) after the town of Jonesboro. It forms the eastern contact of the basin placing Triassic sediments against the Carolina Slate Belt. Reinemund (1955) estimated that the maximum vertical displacement along this fault is on the order of 6000 to 8000 feet. The fault strikes north 35 degrees east in the northeastern part of the county, but changes to a more easterly direction south of Eastwood, where it assumes a strike of about north 60 degrees east. The fault plane dips to the northwest at an angle of about 65 degrees. Reinemund (1955) observed that the Jonesboro fault is displaced by cross faults, although no displacement along the fault was noted in Moore County.

*Western Border Fault*: The Western Border fault forms the western contact of the basin and also places Triassic sediments against the Carolina Slate Belt. Campbell and Kimball (1923) did not recognize the Western Border fault, and Reinemund (1955, Plate 1) has only mapped a few discontinuous faults along the western border of the basin. Authors of both these papers suggested the sediments wedge out to the northwest. They proposed the sediments were once more extensive in that direction, but have been eroded away. This concept might be true of other areas of the Deep River Basin but could not be applied in Moore County.

If the Triassic sediments wedged out to the west, it would be expected that streams would have eroded through the Triassic mantle exposing rocks underlying the basin, producing a scalloped contact. The contact is not scalloped, it is an essentially straight line, suggesting a fault contact. In addition, the fanglomerate, exposed along the western border of the basin in the southern part of the county, indicates that the fault scarp in this area was once a significant topographic feature.

Campbell and Kimball (1923) and Reinemund (1955) considered the Millstone Grit a basal conglomerate. The buried soil under the Millstone Grit indicates that it is not a basal conglomerate and that Triassic sediments had been deposited and weathered before the conglomerate was laid down.

The presence of this fault is further indicated by a gravity survey of the Deep River-Wadesboro Basin conducted by Mann and Zablocki (1961). They stated that in places the basin has graben like features, but suggest that throw of the Western Border fault in the Deep River basin is less than that of the Jonesboro fault.

The Western Border fault is best exposed at the bridge across Deep River, north of Glendon, on the Glendon-Carthage road. It strikes north 30 degrees east and dips to the southeast at 60 degrees. North of Eagle Springs the fault is bent to a more westerly direction and strikes north 55 degrees east. The vertical displacement is unknown but it is thought to be in the same order of magnitude as that of the Jonesboro fault during time of sedimentation. However, post depositional movement along the Jonesboro fault exceeded that of the Western border fault which remained stable, causing the strata to dip to the southeast. The Western Border fault has been displaced in numerous places by cross faults throughout its exposed area.

*Cross Faults*: Northwest trending cross faults are found throughout the Deep River basin. As previously mentioned, along the Western border some of these faults begin in the Carolina Slate Belt and end in Triassic sediments. The major displacement has been parallel to the strike. Vertical displacement is usually minor being on the order of a few tens of feet and occasionally ranging over one-hundred feet. Reinemund (1955) noted the faults extend to great depth because many of them have been intruded by diabase dikes. In Moore County the cross faults trend about north forty degrees west; however, in rare instances, they trend from north twenty degrees west to almost due north. The fault planes are usually at high angles approaching vertical and generally dip to the northeast.

*Longitudinal Faults*: A series of northeast trending step faults, including the Deep River, Governors Creek, and Crawleys Creek faults, lie in a northeast direction across the center of the Deep River basin. These faults have repeatedly exposed the Cumnock formation in the northeastern part of the county. The fault planes dip to the northwest at angles varying from 20 degrees to thirty degrees. The vertical displacement varies from five-hundred to over two-thousand feet. Displacement gradually becomes less to the southeast and all of the faults except the Governors Creek fault die out before they have an opportunity to dip under Coastal Plain sediments.

It is thought that the Governors Creek fault continues across the southern part of the basin, and is a rotational fault with its hinge line near Carthage. The Western block moved down northeast of the hinge line, but up southwest of the hinge line. This explains why, along this fault line, the Pekin formation is in direct contact with the Sanford formation in the southern part of the county and the Cumnock formation in the northern part of the county.

### The Formation of the Deep River Basin

Campbell and Kimball (1923) concluded that the Deep River basin was caused by downwarping of the earth's crust. Sediments were deposited in this trough causing it to continue to sink. After downwarping and sedimentation ceased, the basin was faulted.

Prouty (1931) agreed that the basin was caused by downwarping, but believed the Jonesboro fault developed soon after sedimentation began. He postulated that movement along this fault continued sporadically until sedimentation ceased. This produced a wedge shaped trough, with the thickest sediments next to the fault, becoming progressively thinner away from the fault. The last movement along the Jonesboro fault, as well as the development of faults in the basin occurred after deposition.

The present investigation indicates the Deep River basin in Moore County is a rift valley caused by downfaulting along the Jonesboro and Western Border faults. These faults are thought to have existed in Pre-Triassic time and were reactivated in Triassic time producing the basin. The sequence of event which produced the Deep River basin in Moore County are as follows:

1. Removement along the Pre-Triassic Jonesboro and Western Border faults, during Newark time, creating a graben trough.

2. Disruption of drainage and beginning of sedimentation.

3. Continued movement along the border faults and possible fractional movement along the cross faults with continued sedimentation.

4. Stabilization of the faults with cessation of sedimentation.

5. Removement along the Jonesboro fault, dropping down the eastern side of the basin and tilting the strata to the southeast, accompanied by active movement along cross faults.

6. Development of longitudinal tension faults in the center of the basin.

7. Intrusion of the diabase dikes, predominately along northwest trending cross faults in both the Carolina Slate Belt and Deep River Triassic basin.

## THE COASTAL PLAIN

### Stratigraphy

*Upper Cretaceous Tuscaloosa Formation*: The Tuscaloosa formation is the basal Coastal Plain unit in Moore County. In this report it is divided into a lower and an upper member. The Tuscaloosa formation was named by Smith and Johnson in 1887 after the city of Tuscaloosa, Alabama. L. W. Stephenson (1907) subdivided the Cretaceous of North Carolina into three formations. He called the basal unit the Cape Fear formation. He considered it Lower Cretaceous in age and correlated it with the Patuxent formation of Virginia. He named the overlying unit the Bladen formation, (Black Creek formation in present terminology) and correlated it with the Tuscaloosa formation of Alabama. In 1912 he renamed the Cape Fear formation the Patuxent formation and correlated it, on lithology, with the Patuxent of Virginia and Maryland.

Sloan (1904) named the sands and clays of supposedly Lower-Cretaceous age in South Carolina, the Middendorf Formation. However, Berry (1914) studied plant fossils from this formation and found that they were actually of Upper Cretaceous age. Cooke (1936) correlated the Middendorf formations of South Carolina with the Tuscaloosa formation of Alabama and extended the Tuscaloosa into North Carolina. Horace G. Richards (1950) described the Tuscaloosa formation in North Carolina and stated that it occurred in southern Moore County.

W. B. Spangler (1950) from a study of cuttings obtained from oil-test wells drilled on the North Carolina Coast, found that the subsurface contained both lower and upper Cretaceous beds. He applied the name Tuscaloosa formation only to beds of Eagle Ford-Woodbine age. P. M. Brown (1958) also found rocks of Woodbine and Eagle Ford age in the subsurface stratigraphy of the North Carolina Coastal Plain. These he assigned to the Tuscaloosa (?) formation.

S. D. Heron (1958) mapped the basal Cretaceous outcrops between the Cape Fear River in North Carolina and the Lynches River in South Carolina. He returned to the Classifications of Stephenson and Sloan, dividing the Tuscaloosa formation into the Lower Cretaceous (?) Cape Fear formation and the Upper Cretaceous Middendorf Formation. He named the lower part of the Black Creek formation, below the Snow Hill member, the Bladen member. Heron (1960) stated, "The Middendorf is considered the updip facies of the Bladen member of the Black Creek formation and both of these formations have overlapped the Cape Fear formation."

Groot, Penny and Groot (1961) collected samples containing plant microfossils from the Tuscaloosa formation of the Atlantic Coastal Plain, including one sample from the basal part of the lower member of the Tuscaloosa formation in Moore County.

They found that the Tuscaloosa formation of the Atlantic Coastal Plain is Upper Cretaceous age, but slightly older than Senonian, although some Senonian species are present.

*Lower Member*: The lower member of the Tuscaloosa formation is the basal unit of the Coastal Plain sediments in Moore County. It rests unconformably on both the Carolina Slate Belt and the Triassic Deep River basin. This member is best exposed in the southeastern part of the county, where overlying younger sediments have been stripped away by erosion. It is rarely exposed in the south-central and southwestern parts of the county, where it usually is covered by overlying sediments.

The base of the lower member is exposed in a road cut on the west side of Highway U.S. 15-501 on the south side of Little River. At this locality it is underlain by the Triassic Sanford formation. The basal part of the member is a grey carbonaceous clay containing lignitized wood. The section at this exposure is as follows:

**Section near juunction of Highway 15-501 and Little Rixer**

Top of section covered

| Cretaceous (Tuscaloosa formation member) | Thickness |
|---|---|
| 6. Weathered reddish brown clay | 3′ |
| 5. Dark grey plastic carbonaceous clay | 3′ |
| 4. Fine greyish green sand | 1′ |
| 3. Dark grey plastic carbonaceous clay, containing liginitized wood | 4′ |
| 2. Basal gravel | 6′ |
| Unconformity | |
| Triassic (Sanford formation) | |
| 1. Fanglomerate | 3′ |
| Base of exposure | |

The gray carbonaceous clay of the basal part of the lower member is again exposed in the west bank of a paved road on the south side of Nicks Creek, approximately one mile north of Murdocksville. This locality contains both wood fragments and amber.

The type locality of the lower member of the Tuscaloosa formation is an exposure along the Seaboard Air Line Railroad in the center of the town of Vass. The section at this locality is as follows:

**Section at Vass**

| Recent | Thickness |
|---|---|
| 7. Soil zone, weathered and leached, being colored sand with occasional gravel beds | 6′ |
| Cretaceous (Tuscaloosa formation lower member) | |
| 6. Oxidized, mottled light olive and red clay | 4′ |
| 5. Oxidized, iron cemented, greyish-olive sandstone | 1′ |
| 4. Oxidized, light olive silty clay | 8′ |
| 3. Oxidized, feldspathic, micaceous clayey course olive sand, with occasional gravel beds stained by hematite | 6′ |
| 2. Oxidized, micaceous olive clay, containing some silt and sand | 3′ |
| 1. Unoxidized, micaceous, light grass green sandy clay | 6′ |
| Base of exposure | |

A water well, located approximately one-fourth of a mile northwest of the type locality, drilled for the town of Vass by C. C. Hildebrand and Company, record the following section:

**Log of Water Well at Vass**

| | Thickness |
|---|---|
| 8. White and yellow sand | 4′ |
| 7. Yellow sand clay | 16′ |
| 6. Light yellow and light grey sand clay | 5′ |
| 5. Light grey sandy clay | 10′ |
| 4. Light brown sandy clay | 10′ |
| 3. Water bearing sand | 35′ |
| 2. Light brown sand clay | 15′ |
| 1. Basement rocks of the Carolina Slate Belt | 364′ |

An exposure southeast of Lobelia on the south bank of Little River at Morrison, Bridge, Hoke County, is as follows:

### Section along Little River at Morrison Bridge

Cretaceous (Tuscaloosa formation, lower member)

| | | |
|---|---|---|
| 2. | Festooned cross-bedded micaceous, feldspathic, greyish white and light grey, poorly consolidated sand, containing lignitized logs, grey clay balls, and heavy mineral streaks. (These streaks are composed of as much as 50 percent pyrope garnet. The lignitized logs are partly replaced by plastic grey clay in which growth rings are preserved) | 5′ |
| 1. | Unoxidized light grass green, micaceous, sandy clay | 1′ |

River level

Two exposures of well cemented coarse sandstone occur in the county. One is located northwest of Taylor Town on the north bank of Joes Fork Creek, and the other on the north shore of a private lake, just above Hog Island intersection. Judging from the elevation of the exposure, neither of these outcrops could be far above the base of the unit. The two sandstones are identical in appearance and, if they could be correlated, might be of stratigraphic significance. These sections are as follows:

### Section along Joes Fork Creek northwest of Taylor Town

| Cretacious (Tuscaloosa formation, lower member) | | Thickness |
|---|---|---|
| 3. | Oxidized reddish brown clay | 3′ |
| 2. | Coarse grained, well cemented greyish brown sandstone | 2′ |
| 1. | Oxidized light grey clay | 2′ |

Base of exposure

### Section at Hog Island

| Cretaceous (Tuscaloosa formation, upper member) | | Thickness |
|---|---|---|
| 5. | Basal quartz gravel | 2′ |
| | Unconformity | |
| | (Tuscaloosa formation, lower member) | |
| 4. | Dark grey clay mottled with secondary hematite | 1.5′ |
| 3. | Dark grey clay | 3.5′ |
| 2. | Coarse to medium grained, well cemented greyish brown sandstone | 2′ |
| 1. | Dark grey silty clay | 3′ |

Base of section

A complete stratigraphic section of the lower member of the Tuscaloosa formation in Moore County is not available, but from what is known, it can be stated that the basal part consists of grey carbonaceous clays containing lignitized plant remains and amber, with interbedded thin, grey and olive sand beds. Above the base, the clays become less carbonaceous and lighter grey in color; finally giving way to light olive clayey sand beds containing thin clay beds. Some of the sands exhibit faint graded bedding and cross bedding. Although a few of the clay beds are lenticular in outline, most persist over the exposed outcrop area. In the subsurface some beds can be correlated on electric logs traced over wide areas (P. M. Brown, personal communication).

*Upper Member*: The upper member of the Tuscaloosa formation unconformably overlaps the lower member as well as segments of the Carolina Slate Belt and Deep River basin. The outer limits of the upper member is an irregular contact which can be traced in a northeast-southwest direction across the county. Typical exposures are found in the area around Harris Crossroads; however, measure sections in this unit are of questionable value because of the extreme variable nature of the sediments. For this reason, a type section of the upper member of the Tuscaloosa formation has not been established.

The base of the upper member is exposed at a number of localities along the margin of the Coastal Plain. It is an unconsolidated gravel composed of rounded quartz, varying from one to six inches in diameter. These gravels were probably derived from quartz veins in the Carolina Slate Belt. This basal gravel is thin, usually not over six feet thick, and in some places is totally absent. The basal gravels become finer grained and diminish in thickness to the southeast and might completely disappear down dip. The gravels have a bleached appearance, and might have been subjected to intensive weathering, which removed iron staining, before transportation. Though some of the cobbles show faint pink staining, the absence of iron contrasts with both vein quartz in the Carolina Slate Belt and Recent terrace deposits.

The matrix of the basal gravel is composed of kaolinitic clay and clayey sand. Small quantities of heavy minerals are interspersed through the matrix.

Above the basal gravel, the upper member of the Tuscaloosa formation consists of alternating unconsolidated beds of white clay and clayey sand. The clay beds pinch and swell and sometimes die out. These beds are composed of white plastic kaolinite, which, if weathered, is often stained pink by iron oxide. Quartz grains up to one millimeter in diameter are randomly scattered throughout the clays, and sometimes make up as much as five percent of the deposit. These quartz grains are usually very angular, almost glass clear, and show little or no rounding and frosting. In addition to the quartz, the clays also contain mica shards.

The sand beds usually are more persistent than the clay beds, although they also tend to thicken, thin and occasionally pinch out. Most of the sand beds are relatively massive and are only faintly bedded. Some are crossbedded and others exhibit graded bedding. A few of these deposits contain occasional fine gravel interbeds. Kaolinitic clay galls, varying from one-half to one and one-half inches in diameter, occur sparingly in the gravel beds and along prominent bedding planes. The sands are composed of medium to coarse, sub-rounded quartz grains with mica shards, feldspar grains, and rare heavy mineral streaks along bedding planes. The sands are bonded together by kaolinitic clay. This clay, which is always present, at times makes up as much as twenty-five percent of the sediment.

Thin beds of hematite up to one inch thick occur as a precipitate from groundwater on the upper surfaces of many of the clay beds and along prominent bedding planes in the sand beds.

Hematite and occasionally limonite precipitates, have oftentimes cemented the base of the upper member of the Tuscaloosa formation. These deposits are as much as six inches thick.

*Environment of Deposition*: The lower member of the Tuscaloosa formation was probably deposited in a marine environment. Although marine fossils are lacking in Moore County, they have been recovered from well cuttings down dip (P. M. Brown, personal communication). The persistence of the beds and general rarity of cross bedding suggest these sediments were laid down under marine conditions. The gradual change from grey carbonaceous clays at the base to green and olive clayey sands and thin grass green clay beds above the base, probably represents a change from lagoonal, with stagnant conditions, to marine environment, brought about by transgression of the Lower Tuscaloosa sea.

Other evidence for the marine origin of the lower member of the Tuscaloosa formation is suggested by Heron's (1960) study of exposed basal Cretaceous clays of North and South Carolina. He found that known marine sediments contain abundant montmorillinite, whereas sediments regarded as non-marine contain kaolinite. He found that the Cape Fear formation (lower member, Tuscaloosa formation) contained predominately montmorillinite with some kaolinite, suggesting that it is a marine sediment. The samples collected from the lower member of the Tuscaloosa formation of Moore County were X-ray analyzed by Heron at the request of the author. These were found to contain a majority of montmorillinite over kaolinite (S. D. Heron, written communications). Although montmorillinite as an indicator of marine origin is still open to question by some authors; the present investigation suggests that it is applicable in this case.

The environment of deposition for the upper member of the Tuscaloosa formation has been discussed in the literature. L. W. Stephenson (1923) believed the Patuxent formation to be of alluvial origin, deposited by overloaded streams crossing the Coastal Plain of that period, which existed between the coast line to the east and the highlands to the west.

Veatch (1908) stated that the almost pure kaolinite beds in the Tuscaloosa formation were clearly of sedimentary origin. He postulated that these sediments were derived from deeply-weathered crystalline rocks of the Piedmont in which the feldspar and other aluminus minerals had altered to kaolinite. During Cretaceous time, these weathered rocks were rapidly eroded and deposited along the sea as alluvial fans and at the mouths of streams as deltas. On these deltas fresh water lakes were formed and filled with reworked kaolinite clay. As these lakes were filled, others formed.

Newman (1927) agreed that the clays were derived from weathered rocks of the Piedmont, but postulated that they were leached to essentially pure kaolin in situ in pre-Cambrian time, under the influence of mild climate with heavy rainfall, aided by acid conditions created by decaying vegetation. This weathered material was then eroded, transported by streams, and deposited in a marine environment.

Kesler (1957) agreed with Veatch's deltaic origin, but added that the sediments were derived from a youthful erosion surface. He postulated that the kaolins were formed by weathering of feldspars after deposition of the sediments, and were concentrated by later reworking.

Heron (1960) stated "The sediments of the Middendorf formation (upper member Tuscaloosa formation) probably represent an environment that was dominately fluvial". He suggested that the relatively pure clay bodies, having the shape of small basins, may represent deposition in a floodplain, such as the filling of an abandoned meander.

The upper member of the Tuscaloosa formation in Moore County is considered unfossiliferous although is contains marine fossils down dip (P. M. Brown, personal communication). This fact has led to the development of various theories about its environment of deposition of which too little attention has been paid the source of the sedimentary kaolin beds in the updip facies of the upper member.

In regard to this fact, a residual clay is developed on Carolina Slate belt rocks directly underlying the upper member. It is felt that this residual clay is indicative of the source of the sedimentary clay in the upper member of the Tuscaloosa formation. If the crystalline rocks of the southeast were blanketed prior to Upper Tuscaloosa time, by residual kaolins, which were eroded and deposited during Upper Tuscaloosa time, this would explain the widespread occurrence of sedimentary kaolins in the upper member of the Tuscaloosa formation.

The McKennis pit (see Plate 1, for location) is a typical residual kaolin deposit. The stratigraphic section exposed in this pit is as follows:

**Section of McKennis Clay Pit**

| Recent | Thickness |
|---|---|
| 5. Present day soil zone which extends down from the surface into unweathered gravel | 4′ |
| Tertiary (Pinehurst formation) | |
| 4. Gravel | 1′ |
| Unconformity | |
| Cretaceous (Tuscaloosa formation, upper member) | |
| 3. Pink and white mottled clayey sand | 3′ |
| 2. Basal gravel | 1′ |
| 1. Kaolinitic clay containing quartz veins, still preserving the fine alternating graded bedding of the slates. (The relic bedding strikes north 45 degrees east and dips southeast at 30 degrees) | 2′ |
| Base of section | |

This locality was visited by Mr. E. F. Goldston, North Carolina State College, Department of Soils, at the request of the author. At the time of examination, Mr. Goldston stated the following about the deposit:

1. The Coastal Plain is too thick for the kaolin to have been formed in place by weathering after deposition of the Upper Tuscaloosa member and overlying sediments.

2. A climate capable of producing this degree of weathering and leaching would, of necessity, have been warmer and had more rainfall than present.

A section exposed on the north bank of Little River, where the Murdocksville road crosses the river, is as follows:

**Section of Little River**

| | Thickness |
|---|---|
| Cretaceous (Tuscaloosa formation, upper member) | |
| 4. Sandy clay | 8′ |
| 3. Basal gravel composed of quartz pebbles, ranging in diameter from 1 to 6 inches, in a mtarix of kaolinitic sand | 2′ 6″ |
| Triassic (Sanford formation) | |
| 2. Sandy kaolinitic clay, developed on the Sanford formation grading downward into unweathered red sandstone | 3′ 6″ |
| 1. Red sandstone | 2′ |
| Base of section | |

This section indicates that Triassic rocks as well as the Carolina Slate Belt were highly weathered and leached prior to deposition of the upper member of the Tuscaloosa formation.

Occurrences of residual kaolin underlying the Tuscaloosa formation in Georgia suggest that the pre-Upper Tuscaloosa mantle was an extensive deposit because Munyan (1938) states, "Recently the writer, while mapping Cretaceous rocks (in Georgia) saw a number of contacts between the Tuscaloosa and the underlying crystalline rocks. The crystalline rocks were weathered to primary kaolin in many instances and could be identified as crystallines only by the presence of thin, but continuous quartz veins. The overlying rock could easily be identified as unaltered sediment. In no case observed did it appear that the weathering of the underlying crystalline rocks was due to leaching after the deposition of the sediment".

From this evidence it is postulated that in pre-Upper Tuscaloosa time the Carolina Slate Belt and the Deep River Triassic basin were peneplained and subjected to intensive weathering and leaching under tropical conditions, producing a thick residual kaolinitic mantel. In order to prevent the mantel from being eroded away as fast as formed, the area was, of necessity, relatively flat. If a transgressing sea slowly inundated this peneplaned surface, it would be expected that the upper member of the Tuscaloosa formation would have been laid down in a shallow environmental basin under near shore conditions. Streams emptying into this basin during flood stage, would bring in sediments ranging in sizes from clay to gravel. As the flood subsided the sediments would become finer grained, explaining why some of the sediments contained graded bedding. Cross bedding would be expected in such an environment.

During times when the streams were not in flood stage, they would be carrying colloidal clay, which on entering the basin would slowly settle out as a thick viscous mass. The surface of the basin floor was probably irregular with more clay accumulating in the depressions than elsewhere. This explains why the clay beds pinch and swell.

The next flood would bring in another slurry of coarse sediments which would be deposited on top of the clay beds. The colloidal clays would then act as highly viscous media allowing some of the sand grains from the overlying sediments to settle into the clay, while supporting the remainder. This explains the presence of sand grains in otherwise pure kaolinitic clay.

The coarse basal gravel of the upper member of the Tuscaloosa formation was probably derived from quartz veins which intruded the Carolina Slate Belt. The quartz could have been brought in by streams, however, it has been noted, in many places in Moore County, underlain by rocks of the Carolina Slate Belt, that the surface of the ground is covered by a lag pavement of vein quartz. If areas covered by these lag gravels were exposed to wave action of an advancing sea, this action could rapidly produce a deposit similar to the basal conglomerate of the Upper Tuscaloosa member. As previously noted, the basal gravel is thin, variable in thickness, and in places totally absent. Pettijohn (1957, p. 244) states "blanket conglomerates . . . were deposits of gravel spread out by an advancing or transgressive beach. These deposits are notably thin and patchey; low areas may collect several tens of feet of gravel whereas the intervening high areas may be devoid of any gravel accumulation".

## TERTIARY PINEHURST FORMATION

Gravel beds overly the upper member of the Tuscaloosa formation in Moore County. The gravel deposits near Lakeview were described by Stephenson (1912) and correlated with the Lafayette formation of Pliocene age. Bryson (1930) described a number of gravel pits in Moore County and stated that the exposures are of one group and probably belong to the Lafayette formation. In the Halifax area, Mundorf (1946) recognized graven deposits which he called unclassified high level gravel. He postulated they were probably of differing ages ranging from Cretaceous to Tertiary. Richards (1950) recognized high level gravels in Moore County, but did not attempt to define the distribution or suggest the age. Reinemund (1955) mapped high level gravels in Moore County and stated that they covered almost a fifth of the area shown in his geologic map. He considered all of the Coastal Plain deposits high level gravel, not recognizing the upper member of the Tuscaloosa formation which directly underlies the gravel throughout the county.

The gravels are unfossiliferous and the exact age is not known. In the northeastern part of the State, similar deposits unconformably overlie the late Miocene Yorktown formation (P. M. Brown, personal communication). Although regarded as Pliocene age by Stephens et. al. it is conceivable that these surficial gravels could be Late Miocene, Pliocene, or Early Pleistocene age.

*Stratigraphy*: During this investigation it was found that the so-called high-level gravels could be recognized and mapped as a stratigraphic unit in areas covered by Coastal Plain sediments. It is therefore proposed that this unit be called the Pinehurst formation after the town of Pinehurst which is underlain by these sediments. The type section for the formation is located in the D. H. Wilson sand pit on the north side of Highway 211, approximately one and one-half miles southeast of the center of the town of West End.

The Pinehurst formation unconformably overlies the upper member of the Tuscaloosa formation. This contact is an undulating line, indicating a rough erosional surface developed on the upper member of the Tuscaloosa formation before deposition of the Pinehurst formation. This contact can be recognized at numerous localities in the county; one of the better of these is exposed in the west bank of highway U.S. 15-501 at the Vass road overpass, approximately one and one-half miles southeast of Carthage. This section is as follows:

**Section along Highway 15-501 at Vass Overpass**

| Tertiary (?) (Pinehurst formation) | Thickness |
|---|---|
| 2. Brown limonite stained, faintly bedded, coarse sand; containing lenses of well rounded quartz gravel, ranging in size from one-half to two inches with interspersed kaolinitic clay balls | 10′ |
| Unconformity | |
| Cretaceous (Tuscaloosa formation, upper member) | |
| 1. White kaolinitic clay, pink mottled at the top | 2′ |

In Moore County the Pinehurst formation is a nonfossiliferous sand and gravel which caps all of the higher Coastal Plain hills in central and western Moore County. It has not been observed resting directly on sediments older than the Upper Tuscaloosa.

The Pinehurst formation is exposed on top of the high hill at Carthage, at an elevation of over 500 feet. From this elevation it slopes to the southeast, at first steeply, becoming more gentle down dip until it reaches an elevation of about 350 feet in the southern part of the county.

The gravels on the hill at Carthage range in thickness from 3 to 7 feet and consist of a coarse-brown, iron-stained sand containing lenses of quartz pebbles, ranging in diameter from 2 to 5 inches. Down dip the formation gradually thickens until, in the southern part of the county, it is over 150 feet thick. Bedding and composition rapidly change from coarse sands, containing pebble beds and lenses, at Carthage to festooned cross-bedded sands and fine gravels down dip.

The formation usually is brown or greyish brown in color. It is often iron stained, and sometimes cemented with either hematite or limonite, hematite being the more common. Hematite concretions occur within the formation. The outside of these structures are coated with sand grains. Although they are usually oval or spherical in outline, some have a stair step appearance from preservation of relic bending planes. When broken they are oftentimes hollow and contain hematite powder which local folklore attributes as the source of red Indian war paint. Sometimes this hematite occurs in lumps and when a concentration is shaken emits a sound, from the hematite hitting the walls of the structure; thus giving rise to the common name "rattle rock". Hematite and occasionally limonite is precipitated at the base of the formation in deposits varying from a few inches to over a foot in thickness.

Kaolinitic clay balls are commonly interspersed throughout the formation. They usually occur along prominent bedding planes and in gravel beds. Heavy minerals are much more common in this formation than in the underlying Tuscaloosa, which is relatively devoid of heavy minerals. They are concentrated along bedding planes and are rarely dispersed through the sediment.

The upper surface of these deposits is covered by olive-brown silt and fine sand ranging in thickness from one to five feet. These deposits are attributed to wind action in the form of winnowing. The process was probably aided in the recent past by denudation of the area by forest fires, but is still going on today as can be attested to by observing sparsely vegetated areas on a windy day.

The Pleasant sand pits, between Pinehurst and Aberdeen, contain sediments dissimilar to the other parts of the Pinehurst formation. These deposits consist of water laid, well-sorted, thin-bedded, fine white sands; thin, fissle-bedded, grey silts and plastic clays; and occasional micro-cross bedded fine sands. These deposits are covered by approximately four feet of wind blown silt and fine sand.

Because of the thinness of the Pinehurst formation, the major streams have cut the deposit leaving it capping hills along stream divides and draping down the hillsides. These sand and gravel capped hills are commonly referred to as the "Sand Hills Region". Many times the tops of the hills are concordant, flat, and slope gradually to the southeast. These might represent preservation of original constructional topography.

*Environment of Deposition*: Lithology and absence of fossils suggest the Pinehurst formation is nonmarine. However, it could have, in part, been deposited in a transition zone. In such a zone conditions for preservation of fossils are poor; and, if preserved, they could have been subsequently leached away.

The sediments were derived from a nearby source and carried by vigorous streams in a youthful stage of development, as indicated by the beds and lenses of coarse gravels in the coarse sands around Carthage. A change of environment from stream to deltaic is indicated by comparing these deposits with the cross bedded, finer grained sands and gravels down dip. This change is further suggested by the gradient of the formation which is steepest at Carthage, becoming rapidly less steep, almost flat, down dip. The beds of coarse gravel at Carthage and change in gradient down dip also indicates that one of the major streams emptying into the basin of deposition was located in the general vicinity of Carthage. As sedimentation progressed, deltas grew outward from the mouths of streams emptying into the basin, explaining why the formation thickens down dip.

An interesting feature of the Pinehurst formation is the presence of kaolinitic clay galls. Although clay galls were occasionally observed in Upper Tuscaloosa outcrops, they are universally present in the Pinehurst formation. Whether the kaolinite was derived from erosional outliers of the underlying Tuscaloosa formation or from weathered Carolina Slate Belt rocks is open to debate. Pettijohn (1949) attributes the formation of clay galls to the dessication and breaking up of mud cracks. Mud cracks could have easily formed on mud flats along deltaic distributaries and been incorporated in the sediments when these mud flats were inundated during flooding.

The final product of sedimentation was a series of coalescing deltas, creating a blanket deposit of cross bedded unconsolidated sand and gravel. The fine sands and clays exposed in the Pleasant sand pits were probably deposited in a small fresh water lake, created by blocking of one of the distributaries.

Post depositional wind action in the form of winnowing produced the fine sands and silts which cover the Pinehurst formation in many places.

*Structure*: The Coastal Plain sediments dip to the southeast at six to eight feet per mile. This angle of dip is somewhat steeper than the average for the Coastal Plain, but these are deposits along the ancient coastal margines and should dip more steeply. No faulting has been observed in Coastal Plain sediments even though slicken-sides were observed in Upper Tuscaloosa clays in a borrow pit on the west side of Highway U.S. 1, at the southern city limits of Aberdeen.

Erosional unconformities occur at the base of the lower member of the Tuscaloosa formation and at the base of the Pinehurst formation. The existence of an unconformity at the base of the upper member of the Tuscaloosa formation is suggested by the presence of what appears to be a weathered zone developed on top of the underlying lower member. A basal conglomerate in the upper member also suggests a break in the sedimentation cycle.

### Other Deposits

*Terrace Gravels*: Although Reinemund (1955) mapped four levels of terrace gravels, this author only recognized and mapped three levels in Moore County. The lowest of the terraces (Terrace No. 1, Plate I) is found as scattered remnants along Aberdeen Creek, Little River, and Crane Creek. Sediments underlying this terrace level consists of isolated patches of sand and gravel at elevations from ten to fifteen feet higher than present floodplains. It is light tan-colored coarse sand and well rounded gravel. The gravel fraction is composed predominately of quartz with some Carolina Slate Belt fragments. The gravel is somewhat variable in size, ranging in diameter from 1 to 3 inches.

The most extensive of the terrace deposits (Terrace No. 2, Plate I) occurs from 20 to 30 feet above present floodplains. It is the only terrace level which has developed to any extent on the crystalline rocks of the Carolina Slate Belt. This level occurs along Cabin Creek, north of Robbins, and along the length of Deep River. The terrace deposits consist of yellow-brown fine sands and clayey sand with occasional interbedded silts and fine gravel. The gravels are one-quarter to one-half of an inch in diameter with some ranging upward to over one inch. These deposits are usually covered by 12 to 18 inches of coarse silt and fine sand.

The highest of the stream terraces (Terrace No. 3, Plate I), occurs at elevations of 65 to 70 feet above present floodplains. It is only found along Deep River east of Glendon and Little River north of Mt. Pleasant. Terrace deposits underlying this level are composed almost entirely of gravel with sand and clay filling the interstices. Rare thin interbeds of silty clay are present in the deposit. The subangular to rounded gravels are composed of approximately 70 per cent quartz and 30 percent Carolina Slate Belt rocks. The sand fraction is composed mainly of coarse, angular, quartz grains with occasional feldspar grains.

Soils developed on these deposits have a distinctive red color. The "B" soil horizon is a maroonish-red sand loam, whereas, the "A" horizon is a reddish-brown silty loam.

The three levels of river terraces indicate three periods of downcutting and stream aggradation, followed by deposition of alluvial sediments in the valleys. Therefore, the highest of these deposits is the oldest; the lowest is the youngest with each successive period of cutting lowering the stream and bringing it closer to the present base level. The periods of aggradation were probably caused by a drop in a sealevel; the subsequent deposition by rising sealevel.

The river terrace deposits in North Carolina have been regarded in the literature as Pleistocene age. Successive sets of terraces were supposedly formed due to alternating glaciation and melting producing a rise and fall in sealevel. The terraces in Moore County do not contain fossils and have not been traced into known Pleistocene deposits; therefore, their age determination is left to conjecture.

*Alluvium*: The alluvium filling present stream valleys consists predominately of chocolate-brown and greyish-brown silt with some light and lark grey organic clays. It is conspicuously absent in those parts of the county underlain by the Carolina Slate Belt. However, it is usually present along streams flowing over much of the Triassic basin and Coastal Plain. The presence or absence of alluvium is determined by the relative resistance to erosion or the rocks underlying the streams.

## ECONOMIC GEOLOGY

### Pyrophyllite

Pyrophyllite is a hydrous alminum silicate classified as a high alumina mineral. Its formula is $Al_2O_3.4\ SiO_2.H_2O$ and consists of 66.7 percent $SiO_2$, 28.3 percent $Al_2O_3$ and 5.6 percent $H_2O$. It is used in the manufacture of ceramics, paint, rubber, insecticides, roofing, and paper. Its major production goes into ceramic products and mineral filler. Moore County contains the largest pyrophyllite ore reserves in the United States. This mineral has been mined near Glendon for over a hundred years.

The pyrophyllite at Glendon was originally thought to be talc, until Emmons (1856) reported that it contained aluminum. He called it agalmantolite, a soft material consisting chiefly of pyrophyllite used in the Orient for making carvings. In addition he described the quarry at Hancock's Mill (Glendon) at some length. Brush (1862) analyzed material from Hancock's Mill and concluded that it was pyrophyllite. Pratt (1900) discussed the occurrence of pyrophyllite at Glendon and described Phillips, Womble, Rogers Creek, and other deposits. He noted that the pyrophyllite was often silicified and occurred in iron breccia which merges into pyrophyllite schist. Stuckey (1928) investigated the pyrophyllite deposits of Moore County and discussed their location, size, mode of occurrence, origin, and economic possibilities.

### Pyrophyllite Mines and Prospects

Pyrophyllite deposits occur in four areas in Moore County; namely, north of Glendon, southeast of Hallison, southwest of Robbins, and on Cabin Creek near the Montgomery-Moore county line. Eight pyrophyllite mines and prospects are located on the Glendon fault from McConnell northeast to the county line. This area contains the largest number of deposits in the county. Two pyrophyllite mines are located on the Robbins fault, south of Robbins. Both of these deposits are at present being mined.

*McConnell Prospect*: The McConnell prospect lies approximately 0.5 of a mile northeast of the village of McConnell. The pits are now grown over, but the dumps contain sericite schist and foliated pyrophyllite. Highly sheared sericitized felsic tuff, in part silicified, is exposed along an access road west of the prospect. Exposures available at the time of investigation indicate the shear zone of the Glendon fault in this area is only about forty feet wide and the mineralized zone approximately ten feet wide.

*Jackson Prospect*: The Jackson prospect lies on the south side of Deep River approximately three miles northeast of the McConnell prospect. The shear zone of the Glendon fault in this area is about 200 feet wide. The deposit is located on the fault contact between andesitic tuff to the northwest and slates to the southeast. Two prospect pits have been put down to a depth of about 8 feet. They expose white foliated sericite; however, no pyrophyllite was observed.

*Bates Mine*: The Bates mine is located on the northeast bank of Deep River approximately two miles northeast of the Jackson prospect. Stuckey (1928) stated that this mine was prospected in 1903 and a mill constructed in 1904. The mine was operated until 1919 at which time it closed due to lack of quality ore.

The rock is sheared and mineralized in a zone 150 feet wide, along the Glendon fault. The hanging wall to the northwest is composed of andesite tuff; the footwall to the southeast is composed of slate. The pyrophyllite is developed in a band about three feet wide in the area of major displacement of the fault zone and grades into sericite schist on either side. The ore zone strikes north 70 degrees east and dips northwest at 80 degrees.

*Phillips and Womble Mines*: The Phillips and Womble mines are separated from each other by the Siler City-Glendon road, and lie approximately two miles northwest of Glendon. These mines were mapped by plane table and alidade at a scale of one inch equals 50 feet (see Plate 2) during the field investigation for this report.

The Glendon fault is exposed for approximately 1800 feet along strike in active and abandoned mine workings. The ore body lies in the shear zone of the fault and dips to the northwest at an average angle of 65 degrees. The ore body is lenticular in outline and pinches and swells, but is considerably less in the pinches. Pyrophyllite has also been developed along minor displacements parallel to the main fault.

*White Mine*: The White Mine is located on Rogers Creek approximately 0.8 of a mile northeast of the Womble mine. The ore body is contained between the Glendon fault on the southeast and a secondary reverse fault on the northwest. The ore body is lenticular in outline and dips to the northwest at an angle of 60 degrees. It is exposed along strike in the pit for 375 feet. Recent investigation indicates that the ore body continues to the southwest for a considerable distance. To the northeast it is not traceable beyond the mine. An exposure along the southwest wall of the pit reveals relatively unaltered rock overthrusting the ore body. The direction of movement along this fault was toward the southeast, indicating that the ore body might be overthrust to the northeast. The country rock surrounding the deposit is interbedded slate and andesitic lithic tuff and is stratigraphically in the gradational contact zone between the andesitic tuff and slate units. The contact between mineralized rock and unaltered rock is unusually sharp being gradational for only a few inches or at the most a few feet.

*Jones Prospect*: The Jones prospect lies approximately one and four tenths miles northeast of the White mine. Surface exposures indicate that the rock in this area is highly sheared. Prospect pits reveal foliated pyrophyllite and masses of sericite schist containing chloritoid. The general size of the deposit could not be discerned. As Stuckey (1928) pointed out, the pyrophyllite is considerably iron stained. This staining is probably caused by weathering of chloritoid and might not persist with depth.

*Currie Prospect*: The Currie prospect is located almost on the northern county line, one mile east of the Jones prospect. This prospect lies east of the Glendon fault. The rock in this area is slate, in places, sheared to a sericite schist. Although Stuckey (1928) reported pyrophyllite occurred at this deposit, none could be found during this investigation. The old prospect pits are covered with overgrowth and reveal little about the deposit.

*Standard Mineral Company Mine*: The Standard Mineral Company mine is situated two and one-fourth miles southwest of Robbins. This deposit was discovered in 1918, by Mr. Paul Gerhart, and mining commenced soon thereafter. This operation is the only pyrophyllite mine in the state worked underground. Ore is at present being removed from the eighth level, about 400 feet below the surface.

The pyrophyllite zone is exposed in the mine pit for over 1300 feet continuing beyond the area mapped (see Plate 3). The ore body dips northwest at 50 degrees to 70 degrees and lies in a zone of complicated reverse faulting. In places this faulting has repeated the pyrophyllite zone, making the mineable ore body as much as 150 feet wide. The northeastern half of the deposit is offset to the northwest by cross faulting. The ore body is surrounded by slate which has been sericitized for as much as 300 to 400 feet on either side of the deposit.

*Dry Creek Mine*: The Dry Creek mine is located along the strike of the Robbins fault and lies two miles southwest of the Standard Mineral Company mine. The ore is exposed in two pits located 500 feet apart. It has developed along two thin parallel shear zones (see Plate 5). Ore bodies exposed in the southern pit lie to the northwest of the strike of the northern pit, indicating that the mineralized zone is offset by cross faults. The ore bodies pinch and swell along the strike of the faults, and rarely exceed 20 feet in width. The county rock is highly sericitized slate.

*Ruff Mine*: The Ruff mine is located one and one-half miles southwest of Hallison. The ore body can be traced for over 180 feet. It occurs in a fault zone which strikes north 20 degrees east and dips northwest at 80 degrees. The southeastern limb of the ore body is displaced to the northwest by a cross fault which strikes north 45 degrees west and dips to the northeast at 75 degrees. The mineralized zone averages from 6 to 15 feet wide in the center, but narrows to the northwest and southeast, finally dying out along strike in these directions. The country rock is an andesitic lithic tuff.

*Hallison Prospect*: Pyrophyllite was discovered six tenths of a mile west of Hallison during the reopening of an old gold mine (Stuckey 1928). At this locality several shallow pits have been dug along a quartz vein. The rock in contact with the quartz is a sericite schist containing a minor amount of pyrophyllite. The prospect is located in the shear zone of a north 70 degrees east trending fault, dipping northwest at 55 degrees. This fault forms the contact between felsic tuffs and slates. If any degree of mineralization took place in the slates along this fault there is a possibility of the existence of a workable deposit in the area.

*Sanders Prospect*: The Sanders prospect is located on a hill northwest of the intersection of Cotton Creek and Cabin Creek. The top of this hill has recently been bulldozed along strike of the deposit for approximately 250 feet. This cut exposes sericitized slate which becomes sericite schist near the zone of maximum shear of a north 35 degrees east trending fault, dipping 70 degrees northwest. Sericite developed along this fault can be traced from Cotton Creek northeastward for about 1000 feet. Quartz veins have been emplaced in the center of this fault zone. Pyrophyllite is developed adjacent to the quartz veins, and where it occurs in direct contact with the veins, forms radiating rosettes. The pyrophyllite zone rarely exceeds three feet in width. Weathered pyrophyllite outcrops are highly iron stained; unweathered pyrophyllite is relatively free from staining but contains excessive chloritoid.

### Origin of Pyrophyllite

The pyrophyllite deposits of Newfoundland (Buddington, 1919), North Carolina (Stuckey, 1928) and California (Jahns and Lance, 1950) all occur in rocks of volcanic origin. Buddington (1919), Stuckey (1928), Vhay (1937), Jahns and Lance (1950), and Broadhurst and Council (1953) have all regarded the origin of pyrophyllite as hydrothermal replacement.

Hurst (1959) from a study of the mineralogy of Graves Mountain, Georgia believed that kyanite in the deposit formed under water deficient conditions at high temperature and pressure. The pyrophyllite is thought to have formed by the ingress of water along fractures partially converting kyanite to pyrophyllite.

Zen (1961) from a study of samples collected from various pyrophyllite deposits of North Carolina tended to disregard the effect of hydrothermal replacement solutions on the formation of the pyrophyllite bodies. The presence of three phase mineral assemblage of the ternary system $Al_2O_3$-$H_2O$-$SiO_2$, in his estimation, indicated water acted as a fixed component. However, he further noted that to say water acted as a fixed component did not completely imply the absence of a free solution phase (hydrothermal solutions), such a phase could have existed, but certainly did not circulate freely through the system destroying the buffering mineral assemblages.

From a study of the occurrence of pyrophyllite in Moore County, certain similarities among the different deposits became readily apparent. These deposits are selective to rock type, occur in shear zones of major longitudinal faults, are lenticular in outline, have similar mineralogies, and are zoned.

*Rock Types*: The major pyrophyllite deposits in the county occur in the slate unit. The wall rock in the White mine consists of alternating beds of slate and andesitic tuff, whereas the wall rock of the Ruff mine is composed entirely of andesitic tuff. It is interesting to note that both these rocks are composed of easily sheared water laid, volcanic sediments. No pyrophyllite deposits have been observed in either felsic tuffs or mafic tuffs. This is not meant to imply that pyrophyllite does not occur in these rocks, because it is reported in altered rhyolites in Newfoundland (Vhay, 1937), and in felsic tuffs in North Carolina (Stuckey, 1928); and Broadhurst and Council, (1953). On the other hand, the ability of the slates and andesitic tuffs to readily shear and develop schistosity must have been a factor in the formation of pyrophyllite.

*Faults*: Stuckey (1928) recognized that the pyrophyllite deposits of Moore County occurred in shear zones. During this investigation it was found that the pyrophyllite deposits north of Glendon and southwest of Robbins occur in the shear zones of the Glendon and Robbins faults. Although not studied in as much detail, the Sanders and Ruff deposits also occur in fault zones.

Some of the pyrophyllite pits contain as many as four parallel northeast trending faults. The ore bodies in the White, Standard Mineral Company, and Dry Creek mines have all been offset by cross faults. Pyrophyllite has not developed along these cross faults indicating that they developed after pyrophyllitization.

Low angle thrust faults were observed in the hanging wall of the Womble and White pits. Cross faults in the White pit do not offset the thrust sheet, indicating that thrusting occurred after cross faulting.

*Outline of Pyrophyllite Bodies*: In 1928 Stuckey noted that the pyrophillite bodies were lenticular in outline. This investigation revealed that the ore bodies pinch and swell along their whole length eventually dying out along strike. It also revealed that the bodies all trend northeast and pitch northwest, their development being controlled by major northeast trending, northwest dipping longitudinal faults. Subsurface information made available during this investigation indicates that the ore bodies not only pinch and swell along strike, but down dip as well.

*Mineralogy*: The pyrophyllite deposits all contain the mineral pyrophyllite, sericite, kaolinite, quartz, hematite, and chloritoid. In addition, the fault zone at the Phillips, Womble and Snow properties contain small augen masses composed of pyrophyllite, topaz and diaspore. A sample of this material was collected at the Phillips property. Eldon P. Allen, a staff member of the Division of Mineral Resources, calculated percentages of each mineral present, using microscopic techniques, as follows: 27 percent pyrophyllite, 36 percent diaspore, 37 percent topaz, and 1 percent fluorite. Diaspore has also been reported at the Sanders property (Stuckey, personal communication).

The only crystalline radiating phyrophyllite observed was in contact with vein quartz at the Sanders Property. Fluorite crystals occur in the vein quartz intruding the fault zone at the Phillips Property. Pyrite cubes and chlorite masses are found in the sericitized wall rock at this site. The pyrite cubes are invariably coated by a tissue thin film of quartz, even though the host rock is not silicified. The pyrite cubes on the hanging wall side of this deposit have a rhombic dodechedral face which is absent in the cubic crystals of the footwall.

Silicification is prevalent at the Phillips, Womble, Snow, Dry Creek, and Standard Mineral Company mines. Solutions which brought in this silica in places also introduced copper and gold. Silicified rock in the hanging wall of the Womble pit is stained with azurite and malachite. Silicified rock in the hanging wall of the Standard Mineral Company's pit contains gold which was mined before pyrophyllite was discovered.

*Zoning*: Each of the pyrophyllite deposits observed in Moore County is zoned. Zoning was first noted by Broadhurst and Council (1953), p. 9) who stated: "A large deposit can be divided into three arbitrary units: a very siliceous footwall, a highly mineralized zone, and a sericitic hanging wall".

The outer zone, surrounding the deposits, is a highly sheared country rock, enriched with hematite, chlorite, and chloritoid, which rapidly grades into unaltered rock away from the deposit. The contact between the outer and middle zones is sometimes exceptionally sharp, and occasionally cuts across the regional schistosity. The second or middle zone is a sericite schist still exhibiting faint relic beddings and containing minor chloritoid. This middle zone contains silicified bodies and, in the Phillips pit, chlorite bodies as well as abundant zones of pyrite cubes.

The contact between the middle and inner zones is exceedingly gradational and poorly defined. The inner zone is always composed primarily of pyrophyllite with some sericite and minor chloritoid.

The highest grade pyrophyllite always occurs in the center of this zone in the area of maximum shearing. Schistosity increases toward the center of the inner zone, which is eventually displaced by faulting. These fault planes are almost invariably intruded by quartz veins.

Several generalizations can be made about zoning in the pyrophyllite bodies. These are: Shearing increases inwardly until a zone of rupture is reached, the amount of pyrophyllite decreases outwardly, the amount of chloritoid increases outwardly, and sericite is best developed in the middle zone and decreases both inwardly and outwardly. Therefore, the zoning in these deposits may be classified as: 1. An outer magnesian and iron enriched zone; 2. A potassium or alkali zone; and 3. A high alumina zone.

*Discussion and Conclusions*: The bulk chemical composition of the pyrophyllite deposits is essentially the same as that of the country rock. All of the chemical elements present in the pyrophyllite deposits are present in the country rock, with the exception of fluorine, copper and gold. These elements are associated with quartz veins and silicified zones and were obviously brought in from an outside source. The pyrophyllite deposits could have formed in place, with either addition or subtraction of chemical elements, if the elements were properly segregated and recrystallized into new minerals. A possible sequence of events in the formation of pyrophyllite deposits might be as follows:

1. Intensive folding and low grade regional metamorphism accompanied by faulting.

2. Establishment of a temperature water pressure gradient across the shear zone, with high temperature and pressure in the center diminishing toward the sides. This would cause growth of the lower temperature and pressure minerals chlorite, chloritoid and hematite in the outer zones; the higher temperature and pressure mineral sericite in the middle zone; and the highest temperature and pressure minerals pyrophyllite, diaspore and topaz in the central zone. Water vapor within the system would give the individual iron mobility to move in or out, as the case may be, causing previously existing minerals to be replaced selectively.

3. Invasions of quartz veins, accompanied by silicification and introduction of fluorite, copper carbonates, gold and pyrite as a separate event. In addition, at the Sanders prospect, the quartz veins caused recrystallization of the pyrophyllite in contact with the veins.

4. Removement along many of the faults, accompanied by shearing of the quartz veins.

5. Cross faulting.

6. Minor overthrusting in the areas around the Womble and White pits.

### Gold

*Mode of Occurrence*: Many of the gold mines in Moore County were originally worked as placers. Later, as mining deleted the original stream concentration, mines were opened in the primary ore veins. The largest number of these deposits occur in highly sheared felsic tuffs on the northwest side of the Robbins fault along Cabin Creek.

Some of the ore occurs in rich quartz veinlets. However, the majority is disseminated throughout the country rock on either side of the veins. The ore bodies usually strike northeast and dip northwest parallel to regional schistosity.

Orthoclase feldspars have been observed in some quartz veins suggesting that they were emplaced at high temperature. Pardee and Park (1948) considered the gold lodes of the southeast as high temperature deposits formed at considerable depth. They suggested that they were emplaced during the orogony which occurred at the close of the Carboniferous period.

### Gold Mines

*Clegg Mine*: The Clegg mine is located one and one-half miles west of Robbins. It was originally operated as an open cut mine, but sometime after 1900, two shafts were sunk on the ore vein. The main or Gerhardt shaft reached a depth of 128 feet and the second shaft reached an estimated depth of over 110 feet. The ore was ground on chilean mills and the gold recovered by passing it over riffle boxes. These boxes were eventually replaced by copper plates.

The deposit strikes north 25 degrees east and dips northwest at 75 degrees. The gold is disseminated throughout an ore zone 12 feet wide. The country rock is a felsic tuff sheared to sericite schist. The ore body contains a network of small quartz veinlets and is cross cut by reportedly barren quartz veins.

*Wright Mine*: The Wright mine lies approximately 150 feet northeast of the Clegg Mine. Prior to 1862, a shaft of unknown depth was sunk on this property. A second shaft was completed by J. W. Wright to a depth of 60 feet before the mine was closed in 1912. After grinding the ore on chilean mills, the gold was recovered in riffle boxes.

The ore vein at this mine is a continuation of the vein found at the Clegg mine, and was reported to vary in width from 11 to 20 inches. The ore is disseminated through, what appears to be, highly manganese stained fault gouge.

*Cagle Mine*: The Cagle mine is located 1500 feet southeast of the Clegg mine. The date this mine was first opened is not known, but it is thought to have been operated in 1865 by Charley Overton. The mine operated sporadically until about the turn of the century, when it was closed. An attempt to dewater the old workings was made in 1906, but since that time the mine has laid dormant.

The first shaft, an inclined shaft, reached a depth in excess of 171 feet; a second shaft, approximately 50 feet southwest of the first reached a depth of 265 feet; and a third shaft, further southwest, reached a depth of 180 feet. The ore body was drifted at least 200 feet southwest of the third shaft. A cut extends approximately 300 feet along strike northeast of the first shaft. Six open cuts along the vein were also mined to an average depth of 30 feet.

The center of the ore body is occupied by a blue grey quartz vein, approximately 30 inches wide, containing a large quantity of disseminated pyrite. The gold is dispersed through the quartz as well as the country rock, making the total thickness of the ore zone approximately 60 inches. Assays ran from $4.14 gold and $0.13 silver to $7.54 gold and $1.10 silver in some rich chutes (Nitze and Hanna 1896). The ore body strikes north 27 degrees east and dips to the northwest at 50 degrees.

Chilean mills were originally employed to grind the ore. These were later replaced by stamp mills. At one time as many as 30 stamps were in operation.

*Red Hill Mine*: The Red Hill mine lies approximately 600 feet west of the Cagle mine. The original vertical shaft reached a depth of 100 feet. A drift was extended from this point until it intersected the side of the hill some 250 feet north 15 degrees east of the main shaft. The Red Hill mine was last operated in the early 1900's. No mill was ever erected on the site. For this reason, the gold was hauled to the Clegg mine for grinding.

It is reported that the gold was disseminated through the wall rock, which is a sericite schist derived from shearing of felsic tuff. The ore zone was some 60 feet wide.

*Allen Mine*: The Allen mine is located on a hill 500 feet southwest of the Red Hill mine. On this property a shaft was sunk to a depth in excess of 40 feet. At the bottom of the shaft, drifts were driven out along strike, both to the northeast and southwest. A crosscut was driven into the west side of the hill, opposite the main shaft, but miraculously failed to intersect this shaft.

The ore body is a silicified zone about 35 feet wide. It strikes north 25 degrees east and apparently is an extension of the Red Hill vein.

*Burns Mine*: The Burns mine lies some 1050 feet southwest of the Allen mine. This mine was operated during the 1890's. It was reopened in 1906, and again in 1915, at which time it remained in production for about 18 months before closing.

The ore body strikes north 20 degrees east and dips northwest at 55 degrees. The ore is disseminated through sericite and chlorite schists. A network of quartz stringers occur throughout the ore body. The thickness of the ore zone is not known, but its values averaged $3.00 to $4.50 gold per ton. The mine was worked as a series of open pits up to 50 feet deep.

The soft ore was easily ground on chilean mills, but the harder ore encountered at depth was difficult to grind. To combat this, a 10 stamp mill with bumping tables was installed in 1895 (Nitze and Wilkens, 1897).

*Brown Mine*: The Brown mine lies in a sharp meander of Cabin Creek about 780 feet southwest of the Burns mine. It was worked as an open cut. This cut is about 350 yards long. A few shallow shafts or prospect pits have been put down to depths of less than 40 feet. The mine was last operated about 1905.

Nitze and Hanna (1896) stated that the ore body was about three feet thick and relatively flat lying. They reported that the pay seam was a narrow vein of rich quartz. Some gold was disseminated through the country rock, a brecciated, silicified, sericitized, felsic tuff. The gold was extracted by passing the ground ore over riffle boxes charged with mercury.

*Shields Mine*: The Shields mine is located some 650 feet northwest of the Brown mine. It was operated about 1895 by Cash Shields. The mine consisted of an open cut and one shaft, the depth of which is unknown. The ore shoot was about 30 inches wide and was a schistose sericitized mixture of rock and fine granular clay with numerous quartz veins.

Chilean mills were used to grind the ore and either riffle boxes or copper plates were used to collect the gold.

*California Mine*: The California mine or California shaft is located in the extreme southwestern end of the Standard Mineral Company's pyrophyllite pit.

This shaft was sunk to a depth of 75 feet by Peter Shamburger about 1896. The ore was of low yield and the mine soon closed.

*Dry Hollow Placer Mine*: The Dry Hollow Placer mine was operated along a small stream south of the Standard Mineral Company's pyrophyllite mine. Mr. Ashley Paris supposedly found a 3 ounce nugget in this stream sometime before 1896. The Creek was placer mined intermittently until 1907 at which time a stir mill was installed. The site of the mine is now covered by the pyrophyllite mine dumps.

*Jenkens Mine*: The Jenkens mine is located approximately 1300 feet southwest of the Standard Mineral Company's pyrophyllite mine. This mine was opened prior to 1865 and maintained intermittent production until 1890. In 1912 an attempt was made to reopen the mine by Charlie and Paul Gerhardt. However, all that was accomplished was a successful dewatering of the shafts.

Two shafts have been sunk on the ore vein, a highly silicified cream colored felsic tuff, 3 to 4 feet wide, locally known as crushed flint. The depth of the northeastern shaft is unknown. However, the southwestern shaft reached a depth of 85 feet. Three levels of drifts were supposedly driven along the strike of the ore body. The longest of these is located on the first level and extends about 300 feet. In addition to underground mining, the creek directly south of the shaft has been placer mined.

*Richardson Mine*: The Richardson mine lies approximately 1500 feet southwest of the Jenkens Mine. It is thought to have been first worked by the Marshall Mining Company about 1860. It was operated by Steward and Hewes in 1906.

The ore body appears to be a continuation of the Jenkens vein. It is reported to be about six feet wide and consists of highly silicified tuff containing cross cutting quartz veins. The main vein strikes north 15 degrees east and is about six feet in width. In a distance of about one-fourth of a mile, nine shafts of unknown depths are located along strike of the vein at regular intervals. Drifts were reportedly worked along strike of the ore body at several levels. The mined ore was ground by chilean mills and the gold recovered in riffle boxes charged with mercury.

*Monroe Mine*: The Monroe mine is located one-half of a mile northwest of West Philadelphia. Before the ore vein was located, Mill Creek and its tributaries were placer mined. After the discovery of the gold in situ, a mine was established and operated intermittently until 1900.

The gold is dispersed through a quartz vein as well as the country rock on both sides of the vein, making the total thickness of the pay seam 30 inches. The ore body strikes north 60 degrees east and dips northwest at 48 degrees.

*Bell Mine*: The Bell mine is located one-half of a mile west of Putnam. The mine was reported in production circa 1887 (Kerr and Hanna, 1887), but was abandoned in 1894 (Nitze and Hanna, 1896). Surface exposures indicate the country rock is sericitized felsic tuff, which has evidently been altered near the ore body to a garnitiferous chlorite-sericite schist. The ore zone contains a small percentage of finely disseminated pyrite, and intercalations of siliceous seams from one eighth to four inches in width, as well as small calcite seams. It is four feet wide and strikes north 55 degrees east and dips 75 degress northwest. The ore is said to average $12.00 per ton gold and $0.45 silver. A pay streak, four to eight inches thick is reported to be against the footwall. From one and one-half to two feet of this material was milled and yielded as much as 30 dollars gold per ton. The gold is leafy causing difficulty in an amalgamation of the ore (Nitze and Hanna, 1896).

At present the mine workings consist of numerous open cuts and four open shafts of unknown depth. Nitze and Wilkens (1897) stated that the mine had been worked to a depth of 110 feet and for a length of 800 feet along strike.

*Ritter Mine*: The Ritter mine or McDonald mine is located one-half of a mile northwest of McConnell. It was originally operated sometime prior to 1890, because at that time, it was reopened under the name Teisson mine and remained in production until 1900. The ore body is a highly silicified and sericitized felsic tuff about 3 feet wide striking north 10 degrees east and dipping northwest at 30 degrees. Two shafts about 520 feet apart have been put down on the ore body. The depth of the northeast shaft is in excess of 100 feet; the depth of the second shaft is unknown. During the 1800's the mine employed eight stamp mills to crush the ore.

*Donaldson Mine*: The Donaldson mine, later known as the Cotton mine, lies four tenths of a mile southeast of the Ritter mine. During the late 1850's and early 1860's, it was worked as a placer. Later a shaft was sunk on the ore vein to a depth of about 60 feet and a drift was driven to the southeast along strike for about 75 feet.

The country rock is a highly sheared felsic lithic-crystal tuff. The gold is located in a quartz vein, approximately eight inches wide, as well as disseminated in the country rock in the proximity of the vein, making the total thickness of the ore body about three feet. The quartz vein contains pink orthoclase feldspar phenocrysts which are sometimes stained with azurite and malachite; the altered country rock contains a considerable amount of chlorite.

### Copper

An abandoned copper mine is located one and one-half miles northeast of Glendon on the north side of the Haw Branch road. Two shafts have been put down at this mine. The northeastern shaft is at present open to 150 feet below the surface; the second is caved. A trench about 50 feet long, 10 feet deep and 20 feet wide lies between the two shafts.

The ore body is a highly silicified grey cherty rock which has been brecciated and replaced by feldspar, vein quartz and calcite. The ore body strikes north 30 degrees east and dips northwest at 60 degrees. The thickness of the ore body could not be ascertained, but it is estimated to be about 30 inches. Fault gouge and slickensides are apparent in the country rock.

The primary ore mineral appears to be cuprite, associated with bornite, azurite, and malachite; with a gangue of calcite, chlorite, quartz and orthoclase. A sample of the ore was assayed by the Tennessee Copper Company and ran 0.85 percent copper, 0.02 ounces gold per ton and 0.18 ounces silver per ton.

### Coal

#### Quality and Reserves

Coal was discovered in the Deep River basin about the time of the Revolutionary War (Reinemund, 1955) and has been sporadically mined since that time. The coal beds are limited to the Cumnock formation. The coal is bituminous except where it is locally metamorphosed by diabase dikes into anthracite and natural coke. It has a high heating value, ranging from 12,000 to 14,000 B.t.u. The ash content is low, ranging from 5.8 to 15.9 percent. The sulphur content varies from 2 to 3 percent. The coal has been successfully used in locomotives, heating plants, and steam power plants.

Mining of the coals is complicated by thin steeply dipping coal beds, numerous faults, and intrusives. The major advantages for mining this coal are a large local market and reduced shipping costs, which might allow it to compete with coal brought in from neighboring states. The most easily mined parts of the coal basin lies between the Deep River and Gulf faults, where the coal reaches an average thickness of about 36 inches and dips at angles of less than 15 degrees. This area is also less affected by crossfaulting. (Reinemund 1955).

Reinemund (1955) has calculated reserves at the Murchison mine at 496,000 short tons and at the Gardner mine at 426,000 short tons. The total reserves in Moore County could run as high as 1,500,000 short tons. Reinemund estimates that half this coal is recoverable.

#### Coal Mines

*Murchison Mine*: The Murchison mine lies two and four tenths miles northeast of Glendon, six tenths of a mile northeast of Deep River, and one mile west of the Deep River fault. Emmons recognized coal at the Murchison mine in his 1852 report, and stated that it is reported to be eight or nine feet thick. Coal was shipped from this mine during the Civil War. The mine was most actively operated between 1931 and 1936. At the end of this period the mine was closed because the owners wanted to sell the property and refused to extend the lease. The Cumnock coal bed exposed in the Murchison mine, consists of an upper bench 23.5 inches thick, a middle bench, 36 inches thick; and a lower bench, 2 inches thick (Reinemund 1955).

Several coal pits and prospects are located on the outcrop of the Cumnock bed in the vicinity of the Murchison mine. One lies approximately six tenths of a mile northeast of the mine; and three lie along the south side of the Norfolk and Southern Railroad, one mile south of the mine. The most southerly of these is a drift driven back into the coal bed. The coal bed outcrops along the south side of the railroad one half mile south 79 degrees west of these prospects.

*Garner Mine*: The Garner mine lies seven miles east of Glendon. In 1931 the mine was opened by McConnell and Phillips who operated it until 1933. After 1935, J. M. McIvor took over and operated it for a short time (Reinemund 1955). Since then the mine has remained closed. In 1959, a few hundred yards north of the Garner mine, an attempt was made to strip mine the coal bed. At the time it was thought that the bed was relatively flat lying. However, it was soon realized that the bed was dipping southeast at 19 degrees and the project was abandoned, The Cumnock seam at the Gardner mine was 41 inches thick It consisted of two benches. The upper bench was 11 inches thick. The lower bench contained a two inch shale parting and consisted of an upper bed 15 inches thick and a lower bed 17 inches thick (Reinemund 1955).

### Black Shale and Blackband

Vilbrandt (1927) found that many of the black shales and blackband iron ores of the Cumnock formation, when heated in a closed system, would liberate petroleum and natural gas. His experiments indicated that the shales liberate from 11.4 to 45.6 gallons of oil per ton and from 734 to 3260 cubic feet of gas. He estimated that an average yield would be 30 gallons per ton. Reinemund (1955) stated that this material as a whole, would yield less than 10 gallons of oil per ton. Such a low yield of petroleum would make it unprofitable to mine oil shale in the foreseeable future.

In addition to oil, the shales contain amonium sulphate and calcium phosphate. Reinemund (1955) stated that nearly 100,000 tons of this material removed as a by-product of coal mining, has been sold to fertilizer manufacturers.

Blackband from the Cumnock formation was mined on a limited scale for iron ore just after the Civil War. It was smelted at the old Endor Iron furnace southeast of Cumnock, Lee County (Reinemund 1955). Generally speaking though, this material could only be of value as a by-product of coal mining.

### Stone

The Millstone Grit, a quartz conglomerate in the Pekin formation along the northwestern border of the Deep River Triassic basin in Moore County, was extensively quarried prior to 1900 for millstones. A number of old quarries are located east and southeast of Hallison (see Plate 1 for locations). Inasmuch as millstones are now rarely used, this rock might have value as an ornamental facing stone.

An old brownstone quarry is located in the Sanford formation on Governors Creek, one and three tenths miles southeast of its juncture with Deep River. Several areas of brown sandstone have been observed in the Sanford formation northwest of White Hill. Brownstone was a popular building stone during the 1890's, but is no longer in vogue because it weathers and flakes within a few years.

### Sand and Gravel

#### Pinehurst Formation

The Pinehurst formation contains the most extensive deposits of sand and gravel in Moore County. It has been mined in the areas around Carthage, Eagle Springs, West End, west of Pinehurst and the Pleasant Sand Pit between Pinehurst and Aberdeen (see Plate 1 for location).

The deposit becomes thicker and finer grained, containing less graven down dip. The coarse gravel at Carthage requires crushing before it can be used. However, in most places outside of the Carthage area, the gravels are rarely ever an inch in diamteter and do not require crushing. The sands of the Pleasant Sand Pit contain clay beds, and must be washed before marketing.

In general, the deposits now being worked around Eagle Springs consist of iron stained, structureless, fine sand, overlying the gravels which might represent wind deposits. This material is shipped without being washed or screened.

#### Terrace Gravel

The highest of the stream terraces along the Deep River has been worked in two places, one along the Deep River and the other north of Mount Pleasant. This coarse gravel oftentimes requires crushing before it can be used, and is usually not thick enough to be of great economic importance.

The sands of the middle terrace are widespread over the county, but are usually too thin to be of economic value. Material from this terrace is being worked for sand by the North Carolina State Highway Commission in an area one and one half miles southeast of Lakeview (see Plate 1 for location).

Deposits of the lowest terrace level are being mined by the Becker County Sand and Gravel Company along Little River in the extreme southeastern part of the county. Two large remnants of this terrace level which might be profitably worked occur southeast and southwest of Lobelia (see Plate 1 for location).

#### Upper Member of Tuscaloosa Formation

The basal gravel of the Upper member of the Tuscaloosa formation has not been worked because it usually contains too much overburden, and invariably contains kaolinitic clay which would have to be washed out before it could be marketed.

The upper member of the Tuscaloosa formation contains lenticular shaped deposits of extremely white quartz sand. Unfortunately, these lenses are small and contain minor amounts of kaolinitic clay which would have to be removed before it could be used.

#### Triassic Gravel

A locality in the unnamed upper Triassic unit, which unconformably overlies the Sanford formation northwest of Carthage is composed of a slightly cemented conglomerate. This conglomerate could possibly be utilized after crushing and screening.

## High Silica Quartz

### Vein Quartz

Several large quartz veins have been mapped in the Carolina Slate Belt of Moore County. This quartz might be of value for making optical glass and metallic silicon. Even more important, it might be used as crushed aggregate for facing on decorative cement blocks, which have become popular in construction in the past few years. These quartz veins are described and located as follows:

1. Three quartz veins, the largest of which is 18 feet across, striking north 65 degrees east and dipping northwest at 45 degrees one mile south of Spies on the road between Spies and West Philadelphia;

2. A quartz vein 12 feet thick striking north 25 degrees east and dipping northwest at 75 degrees on the road to Dover, one mile northwest of Dover;

3. A quartz vein 10 feet thick striking north 30 degrees west and dipping vertically on the road to Dover, one half mile southeast of Dover;

4. A large quartz vein striking north 75 degrees east and dipping northwest at 70 degrees on a northeast trending paved road, one half mile due east of Hancock Clay pit; and

5. A quartz vein 15 feet thick striking north 10 degrees east and dipping northwest at 50 degrees on the south bank of Crane Creek, two miles due east of Vass.

### Unconsolidated Quartz Sands and Gravels

An analysis of surficial wind-blown sands in the uppermost part of the Pinehurst formation indicates that they might be used in the manufacture of glass, after washing to remove iron stains. A composite of two analyses of washed samples, taken from sands near Eagle Springs and the Pleasant Sand Pit at Aberdeen is as follows: $SiO_2$ 97.5 percent, $Al_2O_3$ 1.25 percent, $Fe_2O_3$ 0.125 percent (Broadhurst 1949).

As previously noted the basal gravel of the Upper member of the Tuscaloosa formation has a bleached appearance and is not iron stained. This gravel is exposed in outcrop over a wide area along streams near Harris and south of Hill Crest. These gravels would undoubtedly be of high silica content, but are usually too thin and covered by too much overburden to be of value.

## Clay

### Residual Kaolin in the Carolina Slate Belt

The upper member of the Tuscaloosa formation in places overlies deeply weathered and kaolinized rocks of the Carolina Slate Belt.

These residual kaolinite deposits are best developed on one rock type, the slate unit. This was probably due to the fact that the slate has a well developed cleavage making it less resistant to weathering. The clays were preserved because they were covered and protected by the upper member of the Tuscaloosa formation. At present only three clay pits are being operated in this residium.

However, an intensive search in the areas along the margins of the Coastal Plain, where the upper member of the Tuscaloosa formation directly overlies the slate unit might reveal a number of these deposits.

The three commercially operated clay pits are, from east to west, (see Plate 1, for location) the McKennis, Williams and McDuffy pits.

*McKennis Pit*: The McKennis pit was worked on a small scale in 1940, and the clay was used in the filler trade (Broadhurst 1950). Clays developed from weathering of slates in this pit are unstained white to cream colored with a slight greenish cast. They are often cut by minor quartz veins, but appear to be entirely free from grit. These clays are reported to extend 20 to 50 feet below the surface. Iron staining increases with depth.

Results from a series of tests run on clays from this pit by the Department of Engineering, North Carolina State College (Hart 1951, p. 52) are as follows:

"General Physical Properties.
Dry Color; white
Visible Impurities: None
Grinding: Easy. Soft, fine grained clay
Wet Sieve Analysis: 0.5 percent retained on 100 mesh sieve.

Plastic and Dry Properties
Wet Color: White
Plasticity: Good
Extrusion Behavior: Good
Water of Plasticity: 39.1 percent
Drying Behavior: Fair. Slight drying cracks.
Dry Transverse Strength: 124.0 lbs. per square inch.
Dry Linear Shrinkage: 1.9 percent.

Fired Properties.
Rate of Firing: 300° Fahrenheit per hour
Firing Behavior: Poor, Severe cracking and warping
Steel Hardness: Cone 8
Minimum Absorption: 15.1 percent
Cone of Minimum Absorption: Cone 10
Transverse Strength at C-10: 840.0 lbs. per square inch.

Total Linear Shrinkage at C-10: 11.5 percent
Firing Range: Not reached
Vitrification Range: Not reached
Pyrometric Cone Equivalent: Cone 26-Cone 27
Fired Color: Cone 02-Cone 10: White"

To see if material from this pit could be substituted for kaolin in the manufacture of whiteware bodies, two samples were prepared, one of Avery kaolin and the other of clay from the McKennis pit. They were fired together with the following results:

(1) The material from the McKennis pit "Lowers the maturing temperature by approximately three cones.

(2) Decrease the total linear shrinkage by 0.6 percent.

(3) Slightly increases the resistance to thermal shock, and

(4) Has little or no effect upon the color or transverse strength." (Hart, 1955, p. 72).

*Williams Pit*: The Williams pit is in all respects similar to the McKennis pit. The overlying Tuscaloosa formation has been stripped off an area approximately 500 feet long and 200 feet wide, exposing the white clay beneath. The clay is reported by the owner, Mr. Williams, to vary in depth from 15 to 25 feet, depending on weathering. Auger holes indicate the clay underlies several acres in this area. The major production is now used into the manufacture of buff burning brick. Clay from this pit was employed in the manufacture of brick used in restoration of Tryon's Palace, a colonial governor's home at New Bern, North Carolina. (J. L. Stuckey, personal communication).

Material from this pit was tested by the U. S. Bureau of Public Roads (1960) for possible use as an asphalt filler. The clay was found to contain 10 to 45 percent kaolin, 10 to 30 percent quartz and 45 to 65 percent sericite. Because of high plasticity, low wet stability, and low wet strength caused by kaolin and sericite, the material was refused.

*McDuffy Pit*: The McDuffy pit is similar to the other two pits. No information is available about depth or areal extent of this deposit.

### Other Clay in the Carolina Slate Belt

*Pottery Clay*: Moore County contains five pottery manufacturers. The Moore County potters produce designs which are traditional of this region and which were probably brought over from England by the first settlers. In addition some produce designs copied from ancient Chinese vases.

The potters obtain their clay locally from clay enriched subsoils developed on felsic tuffs. Such deposits are never extensive, but are sufficient for the local industry.

*Hancock Pit*: The Hancock pit is located in the northwestern part of the county on Bear Creek, approximately 1000 feet east of the Moore-Montgomery County line. The material in this pit appears to be a quartzose silt, derived from felsic tuff. At the present time, the pit is approximately 100 feet long and 20 feet wide. The material is used in a blend to make buff brick (Mr. J. J. Hume, personal communication).

*Cagle Mine Clay*: Broadhurst (1950, pp. 18-19) reported that white residual kaolin is exposed in workings at the Cagle gold mine, along Cabin Creek. He stated, "The deposit is traceable for nearly 125 feet across strike and extends to a depth of 20 or more feet. About 200 feet east of the Creek similar material is exposed for a short distance along the county road, but was not observed in the creek between the two areas of outcrop. The soft kaolin is fine-grained, light cream to white, and contains some fine grit. The harder semi-weathered material underlying and grading into the kaolins is a light tan greenish tuff . . . (which is) relatively soft and has a somewhat grey appearance indicating the possibility of sericite being present".

This material formed by weathering along a shear bone accompanying the Robbins Fault. Some of the kaolin appears to contain a considerable amount of sericite and might require beneficiation before it can be used.

### Sedimentary Clay in the Deep River Basin

Claystone from the Deep River Triassic basin is extensively used in the manufacture of brick. Two such deposits have been noted in the Pekin formation on the paved road between Harris and Highway N.C. 27. The first of these occurs eight tenths of a mile northwest of Harris and the second lies one and one tenth miles northwest of the first. They appear to be relatively thin and probably are of little economic value.

The most promising deposit is exposed in a stream valley along the Eagle Springs road, approximately one and two tenth miles southwest of Eagle Springs. It is a light grey fissile shale over 10 feet thick and might be of economic value if the cost of removing overburden is not too great. Two other outcrops of clay shale occur in this general area, one located on the Eagle Springs road approximately two miles southwest of Eagle Spring and the other almost on the county line in the valley of a tributary of Drowning Creek, one and one tenth miles south 58 degrees east of Samarcand Manor.

### Sedimentary Kaolin in the Upper Member of the Tuscaloosa Formation

The Upper Member of the Tuscaloosa formation contains sedimentary kaolin deposits similar to those mined in South Carolina and Georgia. These clays are exceedingly white in color. They are not appreciably iron stained, although they are usually discolored by secondary hematite near the surface of bedding planes and along joints and tension cracks.

The clay beds are seldom continuous over a few hundred feet and are rarely over 8 feet thick. Muscovite shards and quartz grains are universally present. Such impurities would probably have to be washed out of the clay before it could be utilized. If a deposit containing several clay lenses were discovered, it might be of economic value.

### Acknowledgements

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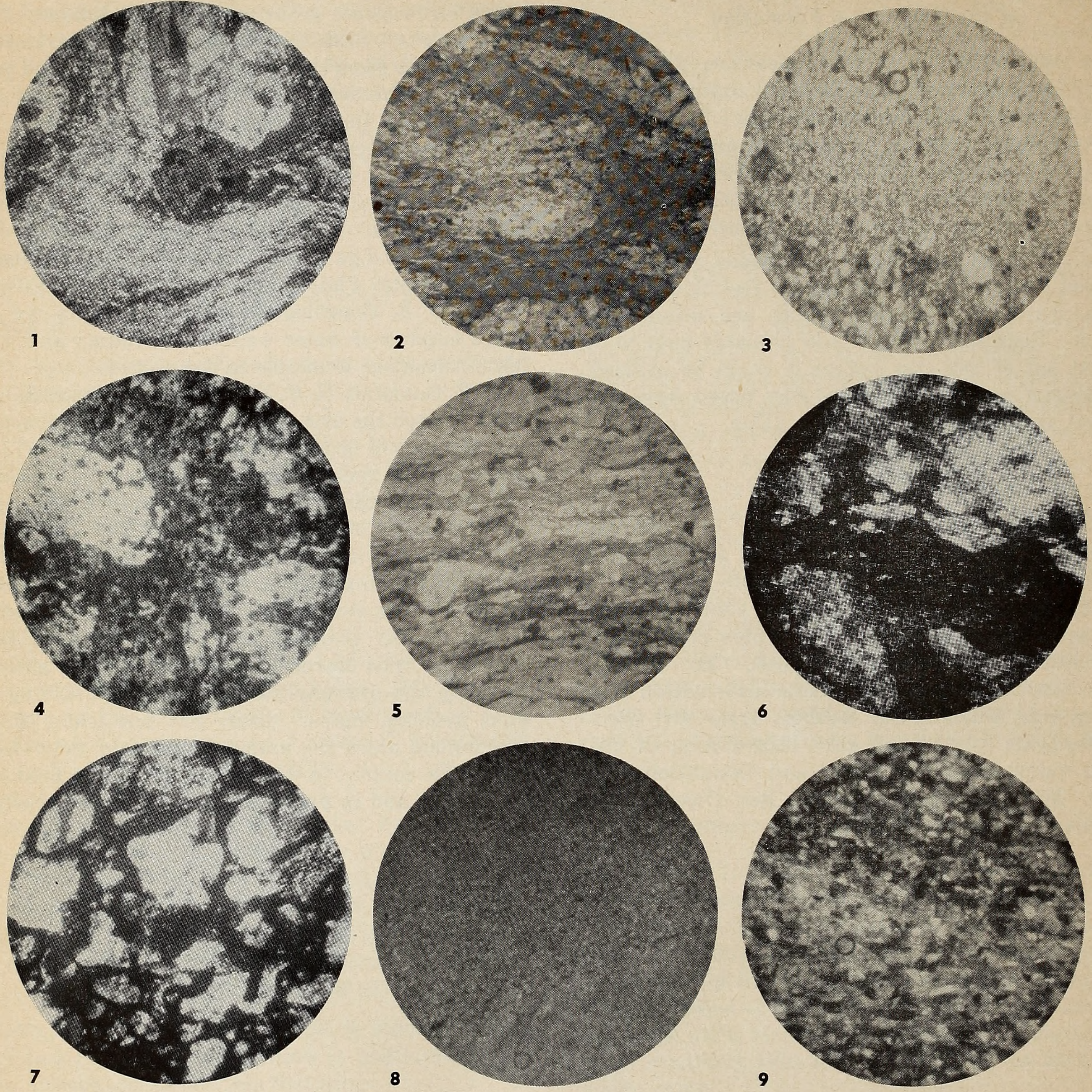

Photomicrographs of Typical Volcanic Rocks

1. Felsic lithic crystal tuff, Lower Volcanic sequence. Diam. 2.5 mm., crossed nicols. Broken lithic and crystal fragments in a groundmass of sericite, kaolinite, and cryptocrystalline quartz.

2. Welded felsic lithic crystal tuff, Lower Volcanic sequence. Diam. 2.5 mm., plain light. Light colored lithic fragments in darker groundmass of devitrified glass, now composed of crytocrystalline quartz, sericite and kaolinite.

3. Flow banding in rhyolite, Lower Volcanic sequence. Diam. 2.5 mm., crossed nicols. Fine textured flow line composed of sericite and cryptocrystalline quartz with coarser grained material on either side composed of feldspar and quartz crystallites and spherulites in a groundmass of cryptocrystalline quartz, sericite and kaolinite. Note the poorly developed secondary lineation caused by slight shearing.

4. Mafic lithic-crystal tuff, Lower Volcanic sequence. Diam. 2.5 mm., crossed nicols. Lithic fragments in a groundmass of chlorite. The small sperical masses are air bubbles.

5. Sheared mafic lithic-crystal tuff, Lower Volcanic sequence. Diam. 2.5 mm., plain light. Augen shaped lithic and crystal fragments in a banded matrix of chlorite.

6. Andesite lithic-crystal tuff, Lower Volcanic sequence. Diam. 2.5., crossed nicols. Lithic fragments and small feldspar laths in a groundmass obliterated by hematite.

7. Amygdaloidal andesite flow. Lower Volcanic sequence. Diam. 2.5 mm., crossed nicols. Quartz amygdules in a groundmass obliterated by hematite.

8. Slate exhibiting graded bedding. Volcanic-Sedimentary sequence. Diam. 2.5 mm., crossed nicols.

9. Graywacke of the type interbedded with slate, Volcanic-Sedimentary sequence. Diam. 2.5 mm., crossed nicols. Note the change in composition and partical size from bottom to top of the bed.

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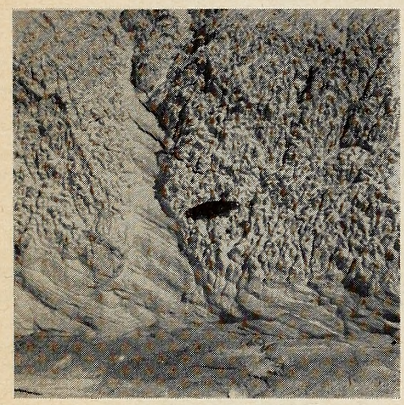

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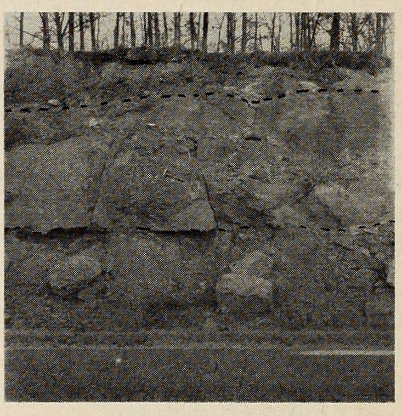

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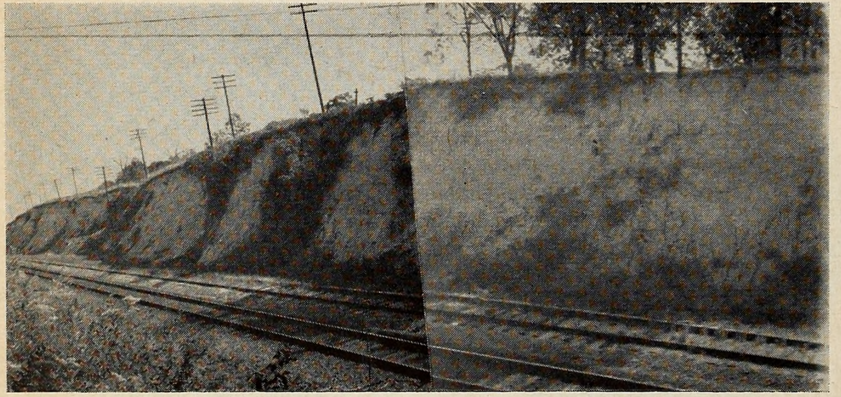

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Photographs of Typical Rock Outcrops

10. Graywacke of the type interbedded with mafic tuff. Cropping out north-northeast of High Falls.

11. Glendon reverse fault (to left) and secondary parallel reverse fault (to right) in south wall of White pyrophyllite mine. Note the drag folding.

12. View of McKennis clay pit, showing Coastal Plain sediments overlying slate weathered to kaolinite.

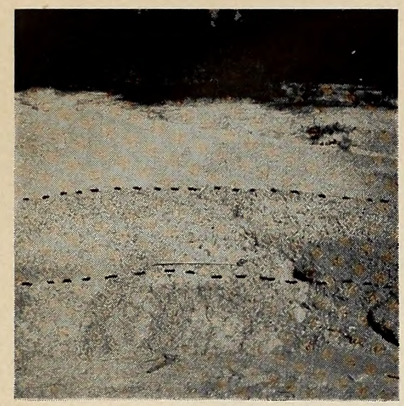
13. Slate, weathered to almost pure kaolinite, but retaining relic bedding, at McKennis clay pit.

14. "Millstone Grit" with carbonaceous weathered and leached zone at base, at Parkwood quarry.

15. Carbonaceous beds near base of the lower member of the Tuscaloosa formation, overlain by sand and clay beds, at Nicks creek north of Murdocksville.

16. Lower member of the Tuscaloosa formation at type locality, Vass.

17. Cemented sandstone near base of the lower member of the Tuscaloosa formation, along Joes Fork Creek northeast of Taylortown.



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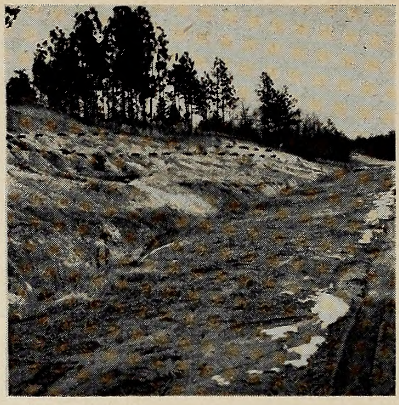

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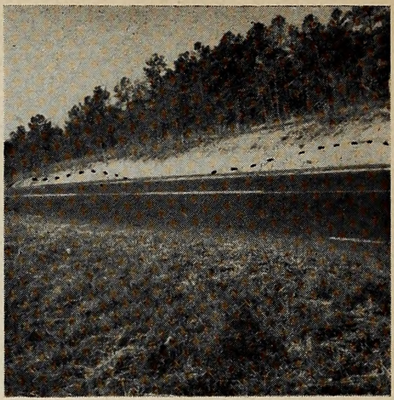

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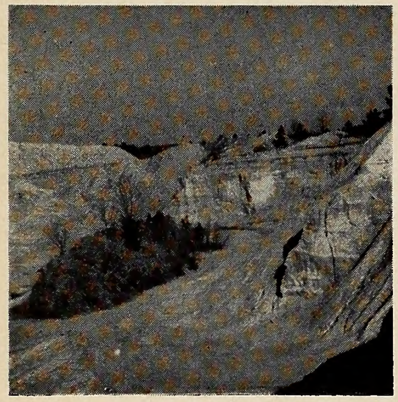

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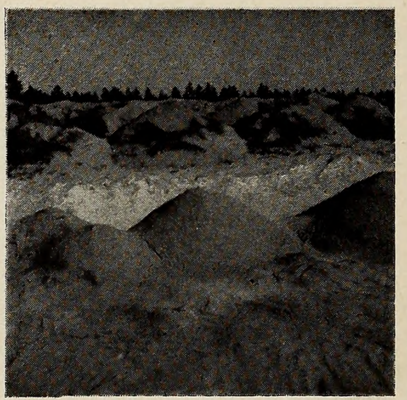

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**Photographs of Typical Rock Outcrops**

18. Contact between upper and lower members of the Tuscaloosa formation, at Hog Island. Note the outlined basal gravel of the upper member.

19. Typical exposure of the upper member of the Tuscaloosa formation, east of Southern Pines. Note the outlined lenticular clay bed.

20. Uncomformable contact between upper member of the Tuscaloosa formation and overlying Pinehurst formation, south of Carthage at Vass overpass.

21. Pinehurst formation at type locality, D. H. Wilson sand pit southeast of West End.

22. Lenticular interbeds of coarse gravel and sand in updip facies of the Pinehurst formation, at Carthage.

23. Typical exposure of cross bedded, hematite stained sand and gravel of the Pinehurst formation at D. H. Wilson sand pit southeast of West.

24. Fissle bedded lake silts in Pinehurst formation at Pleasant sand pit, Aberdeen.

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